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A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains

F. Richard Hauer, Bradley J. Cook, Michael C.Gilbert, Ellis J. Clairain, Jr., and R. Daniel Smith

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Assessing Wetland Functions

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains (ERDC/EL TR-02-21)

ISSUE: Section 404 of the Clean Water Act directs the U.S. Army Corps of Engineers to administer a regulatory program for permitting the discharge of dredged or fill material in "waters of the United States." As part of the permit review process, the impact of discharging dredged or fill material on wetland functions must be assessed. On 16 August 1996, a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) for developing Regional Guidebooks to assess wetland functions was published. This report is in a series of Regional Guidebooks that will be published in accordance with the National Action Plan.

RESEARCH OBJECTIVE: The objective of this research was to develop a Regional Guidebook for assessing the functions of riverine floodplains in the Northern Rocky Mountains in the context of the 404 Regulatory Program.

SUMMARY: The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of the mitigation projects. However, a variety of other potential applications for the Approach have been identified, including; determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

AVAILABILITY OF REPORT: The report is available at the following Web site: http://www.wes.army.mil/el/wetlands/wlpubs.html. The report is also available on Interlibrary Loan Service from the U.S. Army Engineer Research and Development Center (ERDC) Research Library, telephone (601) 634-2355, or the following Web site: http://libweb.wes.army.mil/index.htm. Individuals should arrange for Interlibrary Loan Service either through the library of their business concerns or through the interlibrary loan services of their local libraries. To purchase a copy, call the National Technical Information Service (NTIS) at 1-800-553-6847 or (703) 605-6000, or visit the following Web site: http://www.ntis.gov/. For help in identifying a title for sale call 1-800-553-6847. NTIS report numbers may also be requested from the ERDC librarians.

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Preface

This Regional Guidebook was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Characterization and Restoration of Wetlands Research Program (CRWRP). It is published as an Operational Draft for field testing for a 2-year period. Comments should be submitted via the Internet at the following address: http://www.wes.army.mil/el/wetlands/hgmhp.html. Written comments should be addressed to:

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1 Introduction to the Hydrogeomorphic Approach

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The approach was initially designed for use in the Clean Water Act (CWA) Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified including: (a) determining minimal effects under the Food Security Act, (b) designing mitigation projects, (c) managing wetlands, and (d) long-term monitoring of wetlands.

On 16 August 1996 a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) was published (National Interagency Implementation Team 1996) in the Federal Register. The NAP was developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), Natural Resources Conservation Service (NRCS), Federal Highways Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). Publication of the NAP was designed to: (a) outline a strategy and promote the development of Regional Guidebooks for assessing the functions of regional wetland subclasses using the HGM Approach, (b) solicit the cooperation and participation of Federal, state, and local agencies, academia, and the private sector in this effort, and (c) update the status of Regional Guidebook development.

This document is a Regional Guidebook for Riverine Floodplain Wetlands of the Northern Rocky Mountains. This guidebook provides all the information needed to conduct HGM Functional Assessments for this wetland subclass and includes: (a) the rationale for selecting the wetland subclass, (b) characterization of the wetland subclass, (c) the rationale for selecting the functions to be assessed, (d) the rationale used to develop the assessment models and select model variables, (e) the selection of specific metrics as indicators of wetland function, (f) the data from reference wetlands used to calibrate the model variables, and (g) the necessary protocols for applying the functional indices to the assessment of wetland functions.

The document is organized in the following manner. Chapter 1 introduces the HGM developmental history and outlines the organization of the document. Chapter 2 provides a brief overview of the major components of the HGM Approach and discusses the Development and Application Phases required to implement the approach. Chapter 3 characterizes the geographical extent, climate, geomorphic setting, hydrology, vegetation, soils, and other factors that influence wetland function on riverine floodplains in the northern Rocky Mountains. Chapter 4 discusses each wetland function, model variable, and functional index and provides a summary of wetland functions and variables. Chapter 5 provides the protocols necessary to conduct an assessment using office data, field methods for filling out metric-specific field data forms, and use of computing procedures in the office to calculate Functional Capacity Indices for each function of a project wetland. Chapter 6 provides the user with field data sheets for recording the necessary data. Appendix A presents a Glossary. Appendix B presents documenting data.

2 Overview of Hydrogeomorphic Approach

The HGM Approach to Wetland Functional Assessment is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The HGM Approach includes four integral components: (a) HGM Classification, (b) Reference Wetlands, (c) Assessment Models and Functional Indices, and (d) Application Protocols. The four components of the HGM Approach are integrated into a Regional, Subclass-specific Guidebook, like this document. In the Development Phase of the HGM Approach, research scientists and regulatory managers work cooperatively to select a list of functions and indicators of function that will best represent the functional range of variation among wetlands of the subclass and region. An Assessment Team (A-Team) gathers data from an array of wetlands that represent that range of variation and establish a data set of Reference Wetlands. The functional models and data are combined along with field protocols and methods for analysis to formulate the Regional Guidebook. The end-users then employ the Regional Guidebook during the Application Phase to conduct HGM functional assessments on project wetlands. Each of these components of the HGM Approach are discussed briefly below. More extensive discussions of these topics can be found in Brinson (1993), Brinson et al. (1995), Brinson (1995a,b), Brinson et al. (1996), Smith et al. (1995), Brinson et al. (1998) Clairain et al. (1998), Davis (1998a), Davis (1998b), Hauer and Smith (1998), Smith (1998a,b), Smith and Wakeley (1998), and Wakeley and Smith (1998).

Hydrogeomorphic Classification

Wetland ecosystems share a number of characteristics including relatively long periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these shared characteristics, they occur under a wide range of climatic, geologic, and physiographic situations and exhibit a wide variety of physical, chemical, and biological characteristics (Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a,b; Mitch and Gosselink 1993; Semeniuk and Semeniuk 1995; Cowardin et al. 1979). This variability presents a challenge to the development of assessment methods that are both accurate, in the sense that the method detects significant change in function, and practical, in the sense the

method can be carried out in the relatively short time frame that is generally available for conducting assessments. "Generic" methods, designed to assess multiple wetland types lack the resolution necessary to detect significant changes in function. Consequently, one way to achieve an appropriate level of resolution within the available time frame is to reduce the level of variability exhibited by the wetlands being considered (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function. These criteria are geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform and position of the wetland in the landscape. Water source refers to the primary water source of the water in the wetland such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland.

Based on these three criteria any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995). In many cases, the level of variability in wetlands encompassed by a continental-scale hydrogeomorphic class is still too great to develop assessment models that can be applied rapidly while being sensitive enough to detect changes in function at a level of resolution appropriate to the 404 review process. For example, at a continental geographic scale the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud, Krapu, and Swanson 1989; Hubbard 1988), playa lakes in the High Plains of Texas (Bolen, Smith, and Schramm 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953, Ewel and Odum 1984).

To reduce both inter- and intra-regional variability, the three classification criteria are applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Stewart and Kantrud 1971; Golet and Larson 1974; Wharton et al. 1982; Ferren, Fiedler, and Liedy 1996; Ferren et al. 1996a,b). Regional subclasses, like the continental classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing subclasses in certain regions. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Wetlands Ecology Branch 1998). Slope subclasses might be based on the degree of slope, landscape position, source of water (i.e., throughflow versus groundwater), or other factors. Riverine subclasses might be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Examples of potential regional subclasses are shown in Table 2 and in Smith et al. (1995) and Rheinhardt, Brinson, and Farley (1997).

Table 1
Hydrogeomorphic Wetland Classes at a Continental Geographic Scale

HGM Wetland Class	Definition
Depression	Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or may be closed basins that lack them completely. Water source may come from one or any combination of precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression, but may come from deep aquifer, subsurface springs. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water as evapotranspiration, through intermittent or perennial outlets, or as recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depression wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and river flow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. Spartina alterniflora salt marshes are a common example of tidal fringe wetlands.
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.
Slope	Slope wetlands are found in association with the discharge of groundwater to the land surface or at sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from very gentle to steep. The predominant source of water is groundwater or interflow discharging to the land surface. Direct precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.

(Continued)

Table 1 (Concluded)	
HGM Wetland Class	**Definition**
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are a common example of mineral soil flat wetlands.
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats, in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics, but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are common examples of organic soil flat wetlands.
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional water sources may be interflow or occasional overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In the headwaters, riverine wetlands often intergrade with slope or depressional wetlands as the channel (bed) and bank disappear, or they may intergrade with poorly drained flats or uplands. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwood floodplains are a common example of riverine wetlands.

Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Reference Wetlands

Reference wetlands are the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as human alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally,

Table 2
Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics

Geomorphic Setting	Dominant Water Source	Dominant Hydrodynamics	Potential Regional Wetland Subclasses	
			Eastern USA	Western USA/Alaska
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal marshes	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidirectional, horizontal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (organic soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizontal	Bottomland hardwood forests	Riparian wetlands

the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always the case due to time and resource constraints. Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic, sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, they establish the range and variability of conditions exhibited by model variables. Third, they provide the data necessary for calibrating model variables and assessment models. Finally, they provide a concrete physical representation of wetland ecosystems that can be repeatedly observed and measured. Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for regional subclass at a level that is characteristic in the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. It defines the relationship between one or more characteristics or processes of the wetland ecosystem or surrounding landscape and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands.

Model variables represent the characteristics of the wetland ecosystem and surrounding landscape that influence the capacity of a wetland ecosystem to

Table 3
Reference Wetland Terms and Definitions

Term	Definition
Reference domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected (Smith et al. 1995).
Reference wetlands	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alteration.
Reference standard wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human-altered wetland sites in the least human-altered landscapes. By definition, the functional capacity index for all functions in reference standard wetlands are assigned a 1.0.
Reference standard wetland variable condition	The range of conditions exhibited by model variables in reference standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0.
Site potential (mitigation project context)	The highest level of function possible given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass.
Project target (mitigation project context)	The level of function identified or negotiated for a restoration or creation project.
Project standards (mitigation context)	Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project target is not being achieved.

perform a function. Model variables are ecological quantities that consist of five components (Schneider 1994). These include: (a) a name, (b) a symbol, (c) a measure of the variable and a procedural statement for quantifying or qualifying the measure directly or calculating it from other measurements, (d) a set of values (i.e., numbers, categories, or numerical estimates (Leibowitz and Hyman 1997)) that are generated by applying the procedural statement, and (e) units on the appropriate measurement scale. Table 4 provides several examples.

Table 4
Components of a Model Variable

Name (Symbol)	Measure / Procedural Statement	Resulting Values	Units (Scale)
Sediment delivery (V_{SED})	Potential for sediment delivery to the wetland / visually determine soil grain size, measure slopes and distances of surrounding uplands, determine land use	Continuous from 0 to >100	unitless (nominal scale)
Duration of inundation (V_{DURAT})	Average number of weeks per year that the wetland is inundated (flooded) with water / either measured directly or estimated based on vegetation indicators or Cowardin et al. (1979) classification	0 to 52	weeks (interval scale)
Percent coverage by native vs. non-native plants (V_{NPCOV})	Percentage of each plant community within each wetland zone that is occupied by native plants (coverage).	0 to 100	% (% scale)

Model variables occur in a variety of states or conditions in reference wetlands. The state or condition of the variable is denoted by the value of the measure of the variable. For example, tree basal area, the measure of the tree canopy biomass variable could be large or small. Similarly, recurrence interval, the measure of overbank flood frequency variable could be frequent or infrequent. Based on its condition (i.e., value of the metric), model variables are assigned a variable subindex. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the condition deflects from the reference standard condition (i.e., the range of conditions in which the variable occurs in the reference standard wetland), the variable subindex is assigned based on the defined relationship between model variable condition and functional capacity. As the condition of a variable deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex drops to zero. For example, when the potential for sediment delivery is extraordinarily high, as when the land use factor in the upland, low prairie, and wet meadow zones approach 0.0, the variable subindex score for V_{SED} is 0. In other cases, the subindex for a variable never drops to zero. For example, regardless of the condition of a site or if the entire wetland is covered by non-native plants, V_{NPCOV} will always be greater than zero.

Model variables are combined in an assessment model to produce a Functional Capacity Index (FCI) that ranges from 0.0 - 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the function at a level that is characteristic of reference standard wetlands. Decrease in the FCI indicates the capacity of the wetland to perform the function is less than that which is characteristic of reference standard wetlands.

Application Protocols

The final component of the HGM Approach is the assessment protocol, which consists of specific instructions that allow the end user to assess the functions of a particular wetland area using the functional indices in the Regional Guidebook. The first task is characterization, which involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for model variables. The final task is analysis, which involves calculation of functional indices.

Development Phase

The Development Phase of the HGM Approach is ideally carried out by an interdisciplinary team of research scientists and regulatory managers who form an Assessment Team, or "A-Team." The product of the Development Phase is a Regional Guidebook for assessing the functions of a specific regional wetland

subclass. In developing a Regional Guidebook, the A-Team completes the following major tasks: (a) applying the principles of hydrogeomorphic classification to define and characterize the regional wetland subclass, (b) conceptualizing assessment models and their constituent variables, (c) identifying and collecting data from reference wetlands, (d) analyzing the reference wetland data and describing the relationship between metric variation and index of function, and (e) developing assessment protocols for applying the Regional Guidebook.

After being organized and trained, the first task of the A-Team is to classify the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the Hydrogeomorphic Classification (Brinson 1993; Smith et al. 1995). Next, focusing on a specific regional wetland subclass, the A-Team develops an ecological characterization or functional profile of the subclass. The A-Team then identifies the important wetland functions, identifies model variables to represent the characteristics and processes that influence each function, defines metrics for quantifying model variables, and constructs conceptual assessment models. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass. Field data are then collected from the reference wetlands and used in the revision, calibration, and verification of the conceptual assessment models. Finally, the A-Team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply functional indices in the assessment of wetland functions.

Application Phase

The Application Phase of the HGM Approach involves two steps. The first is using the data collection and assemblage protocols to assemble previously collected data from existing databases (e.g., maps, hydrologic data, soil survey data) and from the collection of site-specific field data collected onsite. These data are then analyzed to develop a site-specific assessment of current wetland functions. The second step is applying the results of the assessment (i.e., Functional Capacity Index) to the specific permit review sequence, which includes alternatives analysis, minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives or results, determination of restoration potential, or identification of acquisition or mitigation sites.

3 Characterization of Riverine Floodplain Wetlands in the Northern Rocky Mountains

Regional Wetland Subclass and Reference Domain

This Regional Guidebook was developed to assess the ecological functions of wetlands of gravel-bed, alluvial riverine floodplains of the northern Rocky Mountains (Figure 1). Throughout the Rocky Mountains of Montana, Wyoming, Idaho, and northeastern Washington, the rivers are largely characterized by a series of attributes that greatly affect their ecological structure and function.

This guidebook is designed to assess riverine floodplains on alluvial gravel-bed rivers in the northern Rocky Mountains. These riverine floodplains are a mosaic of intermittently flooded low riparian terraces and groundwater-driven springbrooks, seeps, scour pools, and backwaters. No specific distinction is made in this assessment procedure between jurisdictional and nonjurisdictional wetlands. It cannot be overemphasized to the users of this guidebook that the wetlands and the ecological functions they provide are inextricably embedded within the context of the floodplain mosaic. Because these systems are highly dynamic, spatially and temporally, in an undisturbed state, wetland by wetland functional assessment is intractable and will ultimately lead to incorrect assessment of function and failure to provide the information needed to make cogent management decisions. Thus, the approach taken in this guidebook is to assess function at the floodplain mosaic spatial scale.

According to Smith et al. (1995) the reference domain is the geographic area that can be applied within the constraints of the reference wetland sites. The reference domain for this guidebook encompasses most of the 4th order and larger streams and rivers of the intermontane glaciated valleys of western Montana, Idaho, northwestern Wyoming, and eastern Washington. The possible extent to which this guidebook may be applied to rivers outside this Reference Domain has been examined. River systems dominated by large substata with broad intermontane floodplains and dominated by orogenic landscapes possess similar structure and function to those given in this guidebook (e.g., Olympic Pennisula, southeast Alaska) and thus may also have similar indicator variables and functional models.

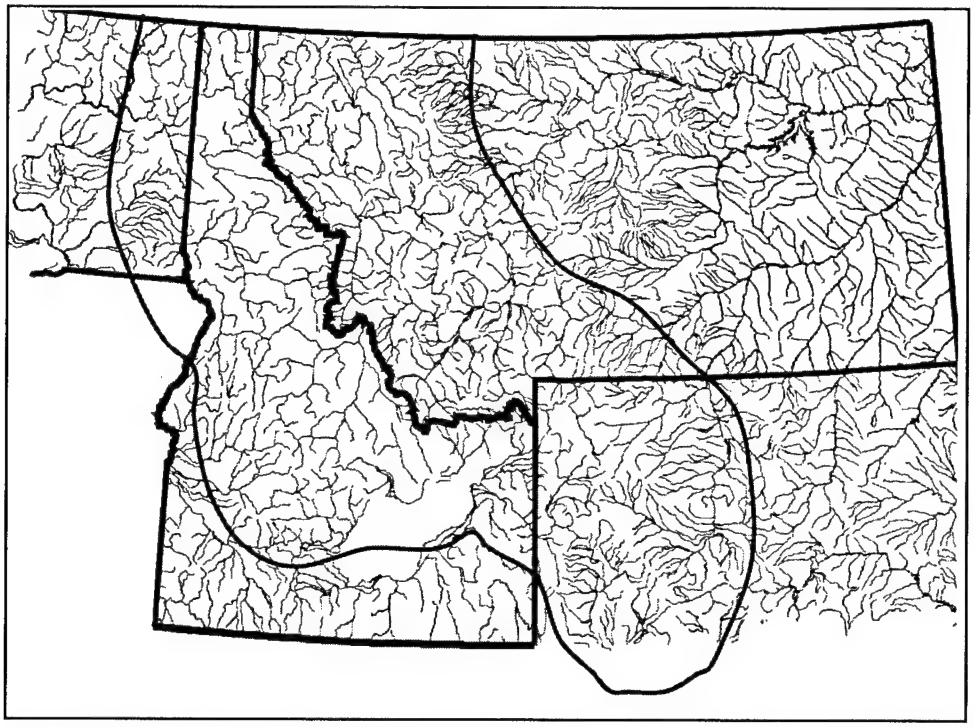


Figure 1. Map of major watersheds in Montana, Idaho, northern Wyoming, and eastern Washington. (The line circumscribes a conservative estimate of the Reference Domain.)

Description of the Regional Subclass

Background

The Rocky Mountains of northwestern Montana are formed of sedimentary bedrock from the late Paleocene to the Proterozoic period that have been affected by low-grade metamorphosis. These mountain ranges are part of the Rocky Mountain Belt Supergroup and consist of argillites, siltites, and carbonates with a maximum stratigraphic thickness of 5,200 m (Whipple et al. 1984). In contrast, the mountains of Idaho and northern Wyoming, including the geographic area of the Bitterroot Mountains and the Sawtooth Mountains of eastern and central Idaho, which comprise the Idaho Batholith, are primarily of granitic origin. Throughout the northern Rocky Mountains, glacial ice has profoundly affected valley geomorphology. Colluvium and glacial till mantle the valleys. During the end of the last major glaciation of the Pleistocene era, about 20,000 years ago, the valleys of western Montana and northern Idaho and Washington were covered by the continental cordilleran ice sheet. The main glacial advance flowed from the cordilleran ice sheet down the Rocky Mountain Trench in Montana and the Purcell Trench in Idaho and along the Rocky Mountain front in the Great Plains of Montana. Smaller valley glaciers flowed from the various mountain ranges (e.g., Livingston, Whitefish, Bitterroot, Absoroka, Garnet) to merge along valley floors and form trunk glaciers as much as 1,000 m thick. Alluvial valley segments of tributary drainages formed with faulting and local accumulations of valley fill from alluvial and glacial sources. Ice dams in the Purcell

Trench in northern Idaho resulted in the periodic filling of Lake Missoula and catastrophic flooding as they broke, sending water across eastern Washington.

The climate of the northern Rocky Mountains of the Idaho panhandle and western Montana is dominated by a Pacific maritime influence. Precipitation in the region generally comes from storms that enter the continental land mass from the central or northern Pacific Ocean. Recent understanding of global atmospheric circulation patterns and the effects of El Niño and Southern Oscillation (ENSO) on regional weather and climate have revealed a cause and effect relationship between Pacific barometric patterns and annual variability in regional precipitation and temperature (Table 5). In contrast, climatic patterns of south-central Montana, northwestern Wyoming, and eastern Idaho are primarily of continental influence (Table 6) with high barometric pressure often dominating winter conditions. The maritime influence in western Montana leads to a wetter climate throughout the year than experienced along the eastern slopes of the Rocky Mountains and the Greater Yellowstone Ecosystem region.

Table 5
Climatic Data at West Glacier, Montana

Month	Average Max. Temperature, F (C)	Average Min. Temperature, F (C)	Average Total Precipitation, in. (mm)	Average Total Snowfall, in. (mm)	Average Snow Depth, in. (mm)
Jan	28.4 (-2.3)	14.8 (-10.8)	3.39 (86)	39.2 (996)	18 (457)
Feb	34.7 (1.7)	18.7 (-8.3)	2.37 (60)	22.6 (574)	21 (533)
Mar	41.9 (6.2)	22.8 (-5.8)	1.85 (47)	14.7 (373)	18 (457)
Apr	52.8 (13.0)	29.7 (-1.4)	1.81 (46)	3.3 (84)	5 (127)
May	64.1 (20.1)	37.1 (3.2)	2.59 (66)	0.4 (10)	0 (0)
Jun	71.2 (24.5)	43.7 (7.3)	3.28 (83)	0.2 (5)	0 (0)
Jul	79 (29.4)	47.2 (9.5)	1.76 (45)	0 (0)	0 (0)
Aug	78 (28.8)	46.3 (8.9)	1.67 (42)	0 (0)	0 (0)
Sep	66.7 (21.7)	38.8 (4.3)	2.04 (52)	0.1 (3)	0 (0)
Oct	52.6 (12.9)	31.8 (-0.1)	2.36 (60)	2 (51)	0 (0)
Nov	37.4 (3.4)	24.9 (-4.4)	3.15 (80)	17.3 (439)	2 (51)
Dec	30.1 (-1.2)	18.5 (-8.4)	3.34 (85)	37.6 (955)	9 (229)
Annual	53.1 (13.2)	31.2 (-0.5)	29.61 (752)	137.4 (3,490)	6 (152)

Notes: Period of record: 10/1/1949 to 12/31/1999.
Data are summaries of average monthly temperature and precipitation in an area dominated by Pacific maritime influence.

Table 6
Climatic Data at Livingston, Montana

Month	Average Max. Temperature, F (C)	Average Min. Temperature, F (C)	Average Total Precipitation, in. (mm)	Average Total Snowfall, in. (mm)	Average Snow Depth, in. (mm)
Jan	34.8 (1.8)	16.2 (-9.9)	0.63 (16)	10.7 (272)	2 (51)
Feb	38.9 (4.3)	18.9 (-8.2)	0.51 (13)	5.2 (132)	2 (51)
Mar	45.1 (8.2)	23.1 (-5.6)	0.93 (24)	10.8 (274)	2 (51)
Apr	56.2 (15.1)	31.3 (-0.4)	1.3 (33)	4.2 (107)	0 (0)
May	65.6 (21.0)	38.8 (4.3)	2.51 (64)	0.2 (5)	0 (0)
Jun	74.1 (26.3)	46 (8.8)	2.16 (55)	0 (0)	0 (0)
Jul	84.6 (32.9)	51.7 (12.3)	1.28 (33)	0 (0)	0 (0)
Aug	82.9 (31.8)	50.3 (11.4)	1.15 (29)	0 (0)	0 (0)
Sep	72 (25.0)	42.7 (6.7)	1.49 (38)	0.2 (5)	0 (0)
Oct	60.7 (17.9)	35.7 (2.3)	1.2 (30)	2.7 (69)	0 (0)
Nov	45.6 (8.5)	26.3 (-3.6)	0.82 (21)	5 (127)	1 (25)
Dec	37.8 (3.6)	20.3 (-7.3)	0.56 (14)	5 (127)	2 (51)
Annual	58.2 (16.4)	33.5 (0.9)	14.55 (370)	44.2 (1,123)	1 (25)

Notes: Period of record: 9/1/1895 to 11/30/1981.
Data are summaries of average monthly temperature and precipitation in an area dominated by Pacific maritime influence.

Overview: What constitutes the river landscape in the northern Rocky Mountains?

River drainage networks throughout the Rocky Mountains are an integral part of the landscape mosaic that forms regional patterns of topography, geochemistry, vegetation, and the bio-physical processes that provide the template for ordering biological systems; including the distribution and forms of wetlands on floodplain surfaces. Physical, chemical, and biological patterns and processes in river networks are structurally and functionally linked and operate across a hierarchy of spatio-temporal scales (Frissell et al. 1986, Minshall 1988). At the landscape scale, the river network is intimately linked to longitudinal gradients (Vannote et al. 1980), riparian vegetation and processes in and around wetlands (Gregory et al. 1991), and surface-subsurface water exchange (Stanford and Ward 1993, Jones and Mulholland 1999). The latter has a profound effect on floodplain water flux.

Stream ecologists have long recognized the interactive relationship between a stream and its landscape (Hynes 1975). The parent material constituting watershed geology determines the availability of ions dissolved in water, resistance to erosion, and geomorphic structure. These variables work interactively with climate to determine runoff patterns, terrestrial soil development, and watershed vegetation. These watershed attributes, in turn, have direct bearing on groundwater, stream hydrology, ion flux, and direct (i.e., autochthony) and indirect (i.e., allochthony) sources of organic matter. The River Continuum Concept (RCC) developed from the idea that river ecosystems present a continuous gradient of biophysical attributes that change along the stream gradient in predictable and observable patterns (Vannote et al. 1980, Minshall et al. 1983). Change in relative diversity of organic compounds, diel temperature flux, biotic diversity, production/respiration (P/R) ratio, and coarse particulate organic matter/fine particulate organic matter (CPOM/FPOM) ratio affect biotic species composition and trophic relationships. The RCC model is particularly responsive to change in the relative degree of autotrophy and heterotrophy, nutrient dynamics, and the transport and processing of organic matter. Changes in these or other variables that tend to be organized as gradients along the river continuum elicit a predictable response from the biota. For example, the harvest of a riparian forest growing along the banks of a small stream may increase solar radiation and stream autochthony and concomitantly reduce allochthonous input to the river. It has been clearly demonstrated that change in litter input from a riparian forest has significant effect on stream biota across multiple trophic linkages (Wallace et al. 1997).

Nutrient cycling is a fundamental feature of nearly all ecosystems. An important concept in developing a landscape perspective of rivers and their associated floodplains and wetlands is that of nutrient spiraling (Webster 1975, Elwood et al. 1983). Spiraling refers to the spatially dependent cycling of nutrients and organic matter as they are affected by the strong down-gradient flow of water. The nutrient spiraling concept provides a conceptual framework for describing the spatial and temporal dynamics of this critical ecosystem function. The concept also allows the quantification of physical and biotic components of the river network that enhance retention and utilization of both nutrients and organic matter and, thus, their effects on ecosystem productivity.

The nature and scope of the river-riparian corridor often changes dramatically from high gradient headwaters to braided middle reaches to meandering lowland sections (Schumm 1977, Church 1992, Stanford and Ward 1993). At the landscape spatial scale, alluvial river systems of mountainous regions are often characterized by alternating confined and unconfined valley segments occurring in series along the stream gradient. Confined valley segments are generally characterized by narrow valley walls, near-surface bedrock, absence of a floodplain, and relatively high stream gradient (Montgomery et al. 1996). In unconfined alluvial segments, streams flow across deposits of gravel and cobble associated with alluvial floodplains (Church 1992). These reaches commonly have a vertical dimension of groundwater-surface water interaction extending tens of meters into the alluvium and a lateral dimension under the floodplain for hundreds of meters (Stanford and Ward 1993) (Figure 2).

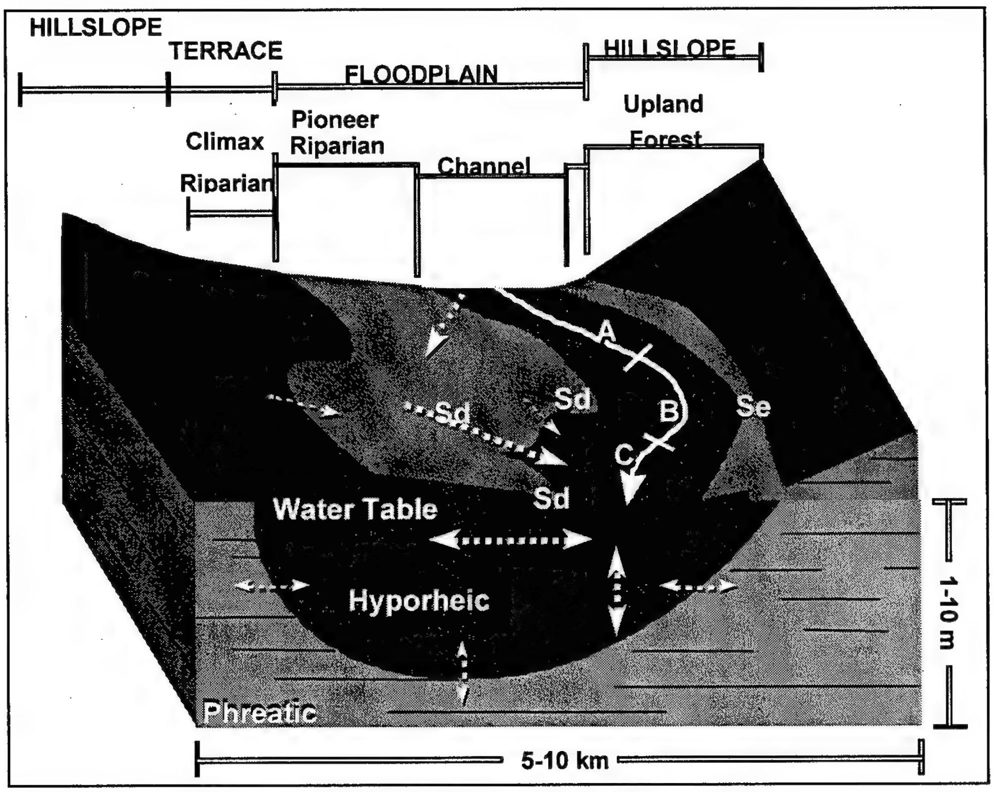


Figure 2. Three-dimensional illustration of groundwater-surface water interaction in gravel-bed rivers and the formation and development of the hyporheic zone (after Stanford and Ward 1988)

A fundamental driver of physical, chemical, and biological patterns and processes of a river network is the spatial and temporal dimension of flooding and the role of riparian and floodplain wetlands in the ecological functions of the riverine-corridor ecosystem. The interaction of climate, geomorphology, hydrologic conditions, vegetation, wetlands, river channel complexity, and floodplain connectivity affect the intensity, predictability, and duration of floods. In the northern Rocky Mountains, the annual hydrograph is dominated by the spring snowmelt period that extends from late March or early April through June (Figure 3).

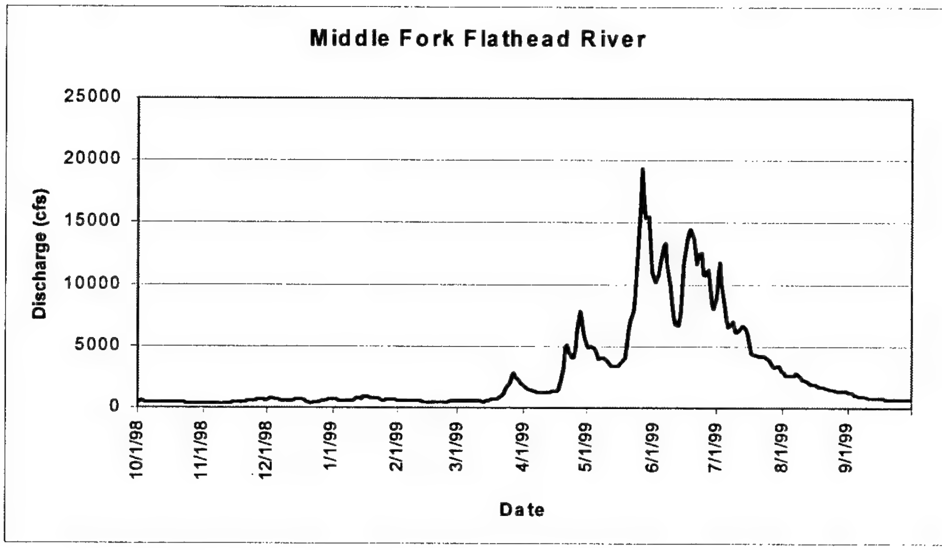


Figure 3. Typical hydrograph of a northern Rocky Mountain river. (The hydrograph illustrated here is from the Middle Fork of the Flathead River near West Glacier, Montana, during the 1999 Water Year.)

Integral to the concept of linkage between the stream and its surrounding landscape are the processes and material transports associated with the interface between the stream and its riparian zone (Gregory et al. 1991). Indeed, this linkage is so profound that the river ecosystem is best viewed from the context of a ribbonlike network composed of a river-riparian corridor intersecting and penetrating the landscape. Along these corridor networks, the aquatic and terrestrial communities interface along ecotonal boundaries characterized by steep biophysical gradients (Naiman et al. 1988). Imbedded within this riverine system is a complex of wetlands that have been created by fluvial processes (Figure 4). The zone of groundwater-surface water interaction, or hyporheic zone, is characterized by differences in substrate porosity that lead to the formation of preferential flow-pathways. This region of the river is now known to strongly affect surface habitats, microbial decomposition, nutrient spiraling, and primary and secondary production and possesses a rich assemblage of hyporheic-specific organisms (Stanford and Ward 1988).

Ecologically, streams and rivers reflect the legacy of their catchments, their geomorphology, hydrologic and climatic drivers, biogeochemistry, and the complexity of their habitat development (Hynes 1970). Inorganic and organic materials are transported downstream from erosional zones characterized by confined stream reaches and high gradients to depositional zone characterized by unconfined reaches and relatively low gradients. Thus, the materials are deposited on expansive geomorphic landforms (i.e., floodplains) that have filled the valley with alluvium. As stated by Stanford (1998), "The process of cut (erode) and fill (deposit) alluviation creates the physical features and characteristics of the river corridor." This process, which results in the transport and deposition of bed-sediments, is also critical to maintaining the zones of preferential flow between

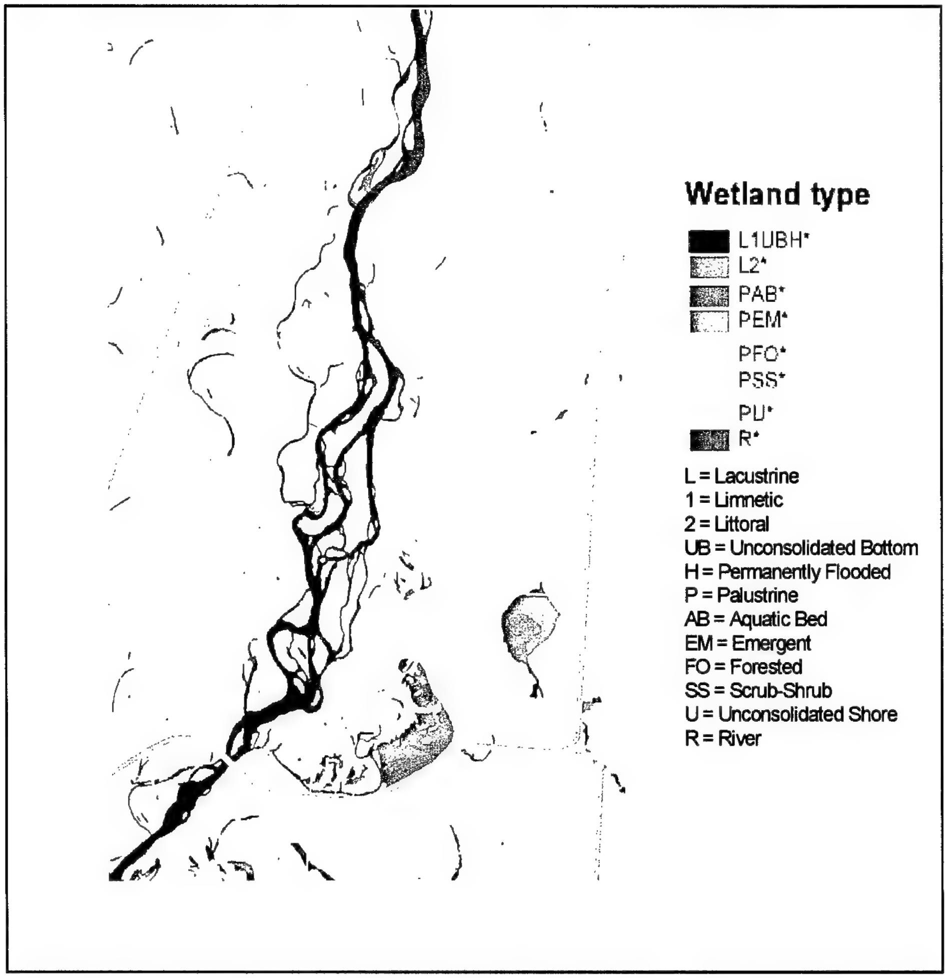


Figure 4. National Wetlands Inventory map of the Flathead River near Kalispell, Montana. (Note the complexity of the riverine corridor and the diversity of wetlands and wetland types distributed along the river floodplain.)

surface waters and hyporheic groundwaters. The floodplain landforms of northern Rocky Mountain river corridors are viewed correctly when placed in the context of a dynamic mosaic of habitats that transition between saturated and unsaturated conditions in both time and space and act as interconnected patches on the floodplain surface and below ground (Figure 5). Many of these features can be easily recognized on the surface of the floodplain using aerial photographs (Figure 6). See Figures 7-14.

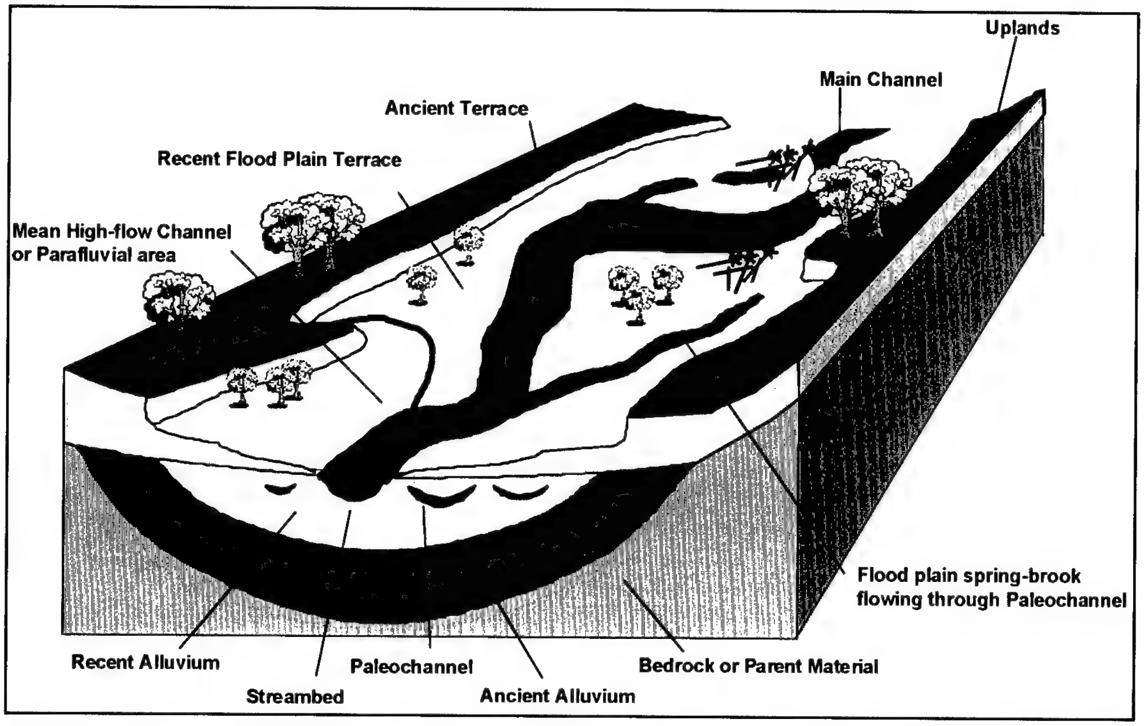


Figure 5. Schematic model of a floodplain in the reference domain of the northern Rocky Mountain ecoregion. (The model illustrates the extent of underground connectivity between the main channel and the subsurface and surface paleochannels.)

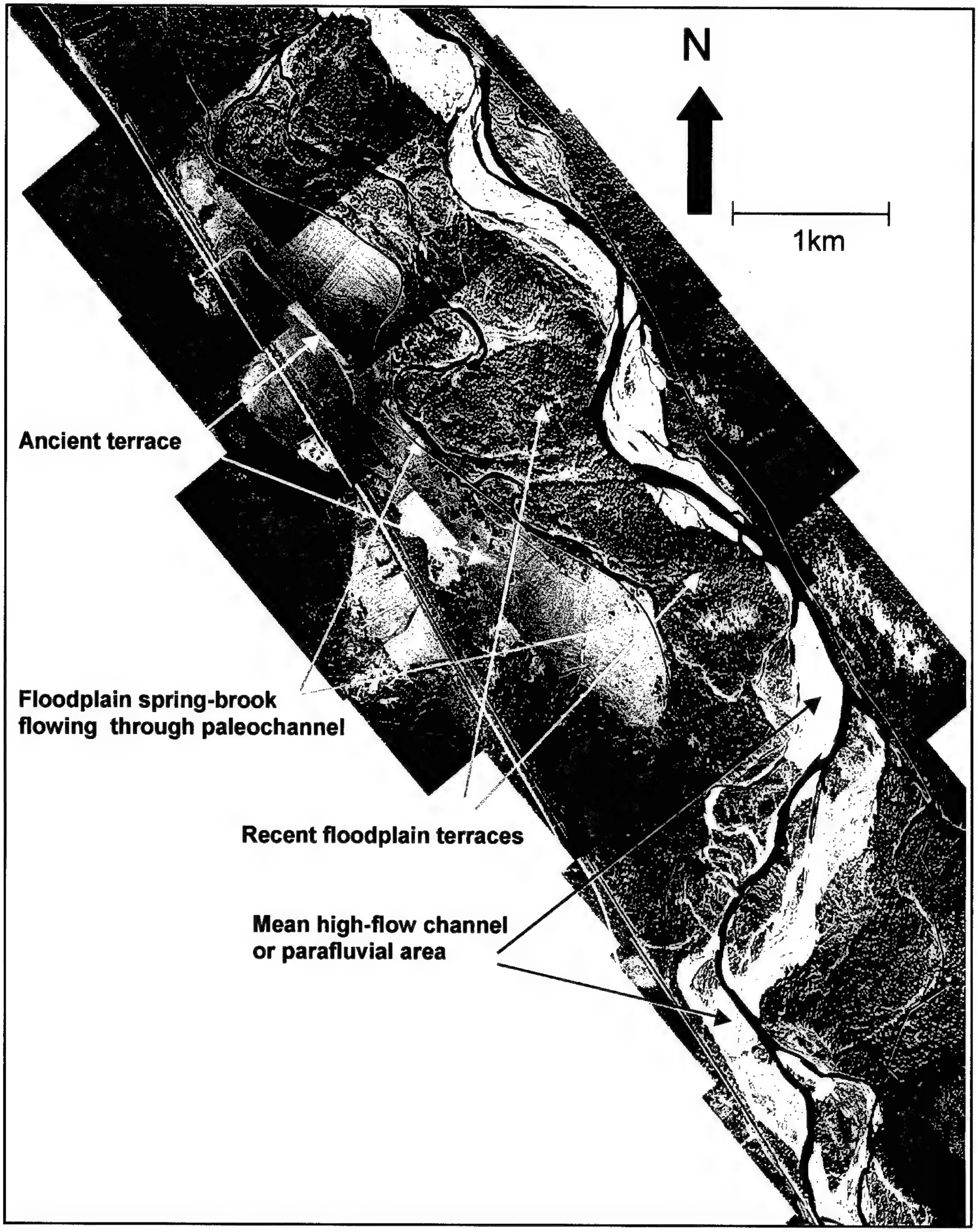


Figure 6. Composite aerial color infrared photographs of the Nyack floodplain on the middle fork of the Flathead River. (The main channel is at low flow. Several prominent surface features important to the ecological function of the floodplain and its embedded wetlands are demarcated. The active modern floodplain is within the red lines on the composite photo.)

Figure 7. Epilithic bacteria transform organic matter entrained from the river and floodplain into plant-available N and P which stimulates hot spots of productivity where groundwater upwells to the surface within the floodplain shifting habitat mosaic

Figure 8. Bed-sediments of river floodplains may contain zones of preferential flow (paleochannels) that reflect the legacy of cut and fill alluviation and function as injectors and drains for the alluvial aquifers

Figure 9. Dense vegetation along a paleochannel maintained by upwelling of hyporheic groundwater

Figure 10. Paleochannel maintained by upwelling of hyporheic groundwater

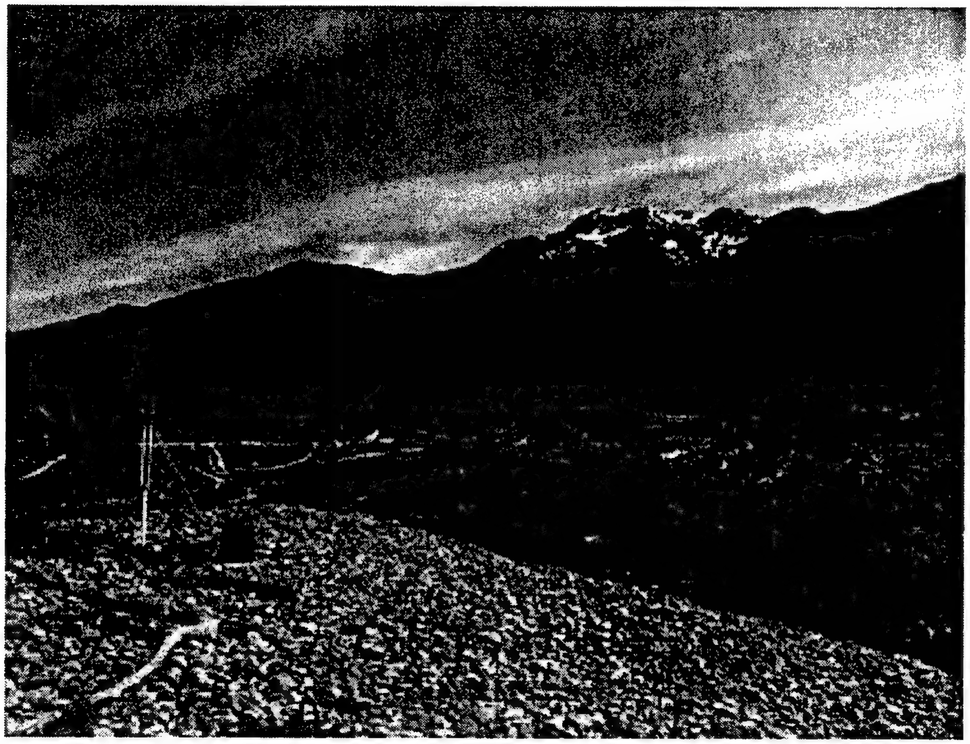


Figure 11. Channel avulsion mediated by large wood producing a new channel with the potential to become the new main channel

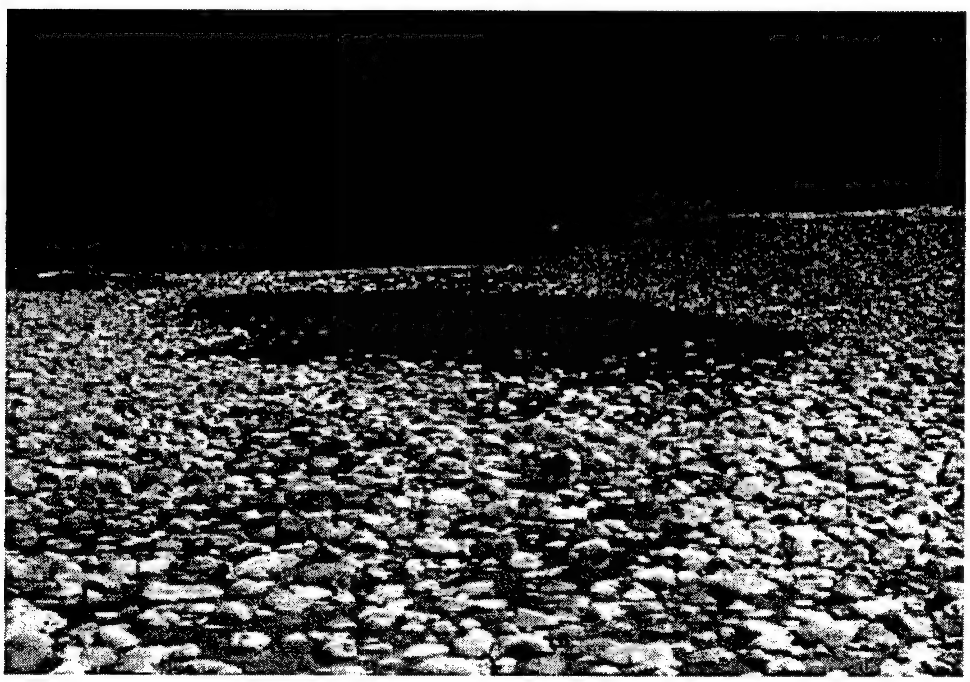


Figure 12. Groundwater upwelling in recently abandoned channel

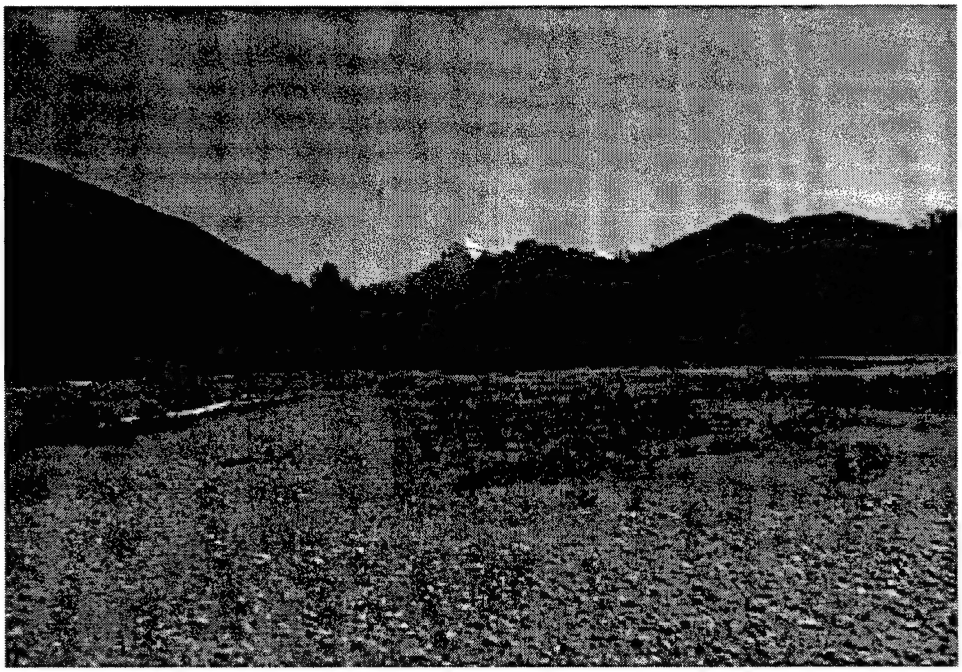


Figure 13. Deposition and recruitment of vegetation on banks associated with recently abandoned channel

Figure 14. Abandoned old main channel, now a springbrook and flood channel flowing through an old growth forest on the floodplain

4 Assessment Approach, Variables, Functions, and Models

The riverine wetlands of the reference domain addressed in this guidebook occur exclusively in the unconfined river reaches characterized by expansive floodplains. It is not recommended that users attempt to assess wetlands with this guidebook that may occur sparsely and in a narrow riparian fringing bank along the edges of the river corridor in confined reaches.

The wetlands that occur on river floodplains of the reference domain are ecologically extremely diverse. For example, floodplain wetlands may range in size from only a few square meters of temporarily inundated scrolling depressions in a forested terrace to a large, ancient-channel depression that is permanently flooded. Likewise, there are many surface habitats that are distributed across the contemporary floodplain and do not meet jurisdictional criteria, yet are ecologically functioning riparian/floodplain wetlands. Based on the author's experience, it is not ecologically sound to separate riverine wetlands from their surrounding floodplain context. Riverine wetlands of this reference domain always occur as embedded features within a floodplain mosaic that function "properly" or "characteristically" only within the floodplain framework.

Since the purpose of any HGM functional assessment guidebook is to provide an ecologically sound and representative evaluation, the approach taken in this guidebook is to assess the floodplain as a functioning unit rather than assessment of individual wetlands, as is common in the HGM approach to functional assessment. A "classic" wetland delineation across a "wetland assessment area" of 2-3 ha may easily lead to tens or even hundreds of individual jurisdictional wetlands. Focus on individual wetlands will not only create an intractable hierarchy of wetland classification, but will also lead to false evaluation of system function. In turn, such an approach will result in failure of HGM as an ecological evaluation tool and as a regulatory tool for this wetland type.

In summary, the functional assessments done through this guidebook focus on the ecological function of a floodplain segment that operates as an ecological unit with riverine wetland embedded within the floodplain mosaic.

Overview

The following functions are performed by riverine floodplains and their associated wetlands in the northern Rocky Mountains.

a. Surface-Groundwater Storage and Flow

b. Nutrient Cycling

c. Retention of Organic and Inorganic Particles

d. Generation and Export of Organic Carbon

e. Characteristic Plant Community

f. Characteristic Aquatic Invertebrate Food Webs

g. Characteristic Vertebrate Habitats

h. Floodplain Interspersion and Connectivity

The following sequence is used to present and discuss each of these functions and the variables and models on which the assessment is based.

a. *Definition.* Defines the function and identifies an independent quantitative measure that can be used to validate the functional index.

b. *Rationale for Selecting the Function.* Provides the rationale for why a function was selected and discusses onsite and offsite effects that may occur as the result of lost functional capacity.

c. *Characteristics and Processes that Influence the Function.* Describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lays the groundwork for the description of model variables.

d. *Description of Model Variables.* Defines and describes each of the variables in the assessment model.

e. *Functional Capacity Index.* Describes the assessment model from which the functional capacity index is derived and discusses how model variables interact to influence functional capacity.

Floodplain Cover Types

The floodplains of the northern Rocky Mountains are very complex, structurally and ecologically. The following Cover Types (Table 7) capture the most common types of surfaces on the river floodplain complex. However, this

Table 7 List of Cover Types Prevalent Among the Floodplain-Wetland Complexes of Alluvial Gravel-Bed Rivers of the Northern Rocky Mountains	
Cover Type	Description
1	Mature conifer dominating the canopy, with interspersed mature cottonwood. Soils generally developing an A-horizon.
2	Mature cottonwood dominated (>6-m height and >10 cm dbh), may have early stages of conifers that have not reached the forest canopy or may be entirely devoid of conifers.
3	Immature pole cottonwood 2-6 m in height and <10 cm dbh. May also have interspersion of willow. Soils are generally cobble dominated with fine sediments accumulating over the surface.
4	Cottonwood or willow seedlings and early seral stages up to 2 m in height. Substrate often with exposed cobble, but may also include deposited fines from flooding. Generally, soils are unstained by organics, indicating very early soil development.
5	Filled or partially filled abandoned channel dominated by mix of willows, alder, shrubs, and interspersed herbaceous cover. Also, often the dominant Cover Type along edge of backwaters. Soils are generally composed of deeper fines (>10 cm) with a developing A-horizon
6	Herbaceous vegetation dominated, but may have interspersion of an occasional shrub (<10% of cover). This Cover Type is often associated with a filled side channel or abandoned back channel, but may be on any surface type.
7	Exposed cobble riverbed during base flow and inundated during most annual high flows. May have very sparse herbaceous vegetation or an occasional cottonwood or willow seedling composing <10% cover.
8	Main-channel surface during base flow, may be in a single tread channel or may be braided w/ islands.
9	Off main channel, water at the surface during base flow; includes springbrooks, oxbows, scour depressions and ponds, non-flow-through downstream connected side channels, and disconnected side channels.
10	Agricultural field, may be a meadow or plowed, often planted and hayed, may have origin as a forested surface, but now logged, or may have been a natural meadow.
11	Domestic or commercially developed land including homes, buildings, gravel pits, transportation corridors, etc.

list is not exhaustive. Whenever a coverage does not appear on this list, it is at the discretion of the assessment team to appropriately evaluate which coverage type it most closely approximates and apply appropriate levels of impact and weighting to the variable subindex scores.

Functions and Assessment Models

Function 1: Surface-Groundwater Storage and Flow

Definition. The function Surface-Groundwater Storage and Flow is defined as the capacity of the river, floodplain, and associated wetlands to dynamically store and route water primarily under the influence of surface and subsurface flow. This generally occurs dynamically in the northern Rocky Mountains as spring snowmelt from the watershed increases river discharge and thus river stage height (Poff and Ward 1989). The agraded floodplains of the Reference Domain are generally characterized by braided conditions within agraded channel networks and a highly developed system of side channels and surface

and subsurface paleochannels (Stanford 1998). Flooding of the floodplain and the channel network across the floodplain surface may also occur at other times of the year from heavy precipitation.

Potential independent measures of this function can be obtained by monitoring water-stage-height recorders at key nodes of water flow and connectivity on the floodplain, monitoring of groundwater wells distributed across the floodplain with particular emphasis placed on subsurface paleochannels, and extensive spatial measuring of vertical hydraulic gradient.

Rational for Selecting the Function. Performance of the function is essential to the performance of virtually all other characteristic floodplain functions and separates the role of the floodplain on the larger landscape from various upland environs. If a floodplain has been geomorphically modified (e.g., dikes, levees) to prevent flooding or the hydrologic regime of the river has been modified to prevent flooding (e.g., dams, diversions), the floodplain and associated mosaic of wetlands cannot function characteristically. Storage and flow of water throughout the floodplain are required for development and support of characteristic nutrient cycling, generation and export of organic matter, and maintaining essential habitats for both terrestrial and aquatic species.

This function has a significant effect on other functions, such as development of fine soils (i.e., silt import and organic matter deposition from floodplain vegetation) and redox conditions that promote nitrogen cycling (Mausbauch and Richardson 1994). This function also has a very significant impact on aquatic invertebrate populations. Some aquatic invertebrates (e.g., midges) have very rapid life cycles and are highly adapted to ephemeral habitats. However, many species (e.g., mayflies, caddisflies, dragonflies) have much longer life histories and require flooded conditions virtually throughout the year (Merritt and Cummins 1996). Various vertebrates are obligatorily associated with aquatic environments for all (e.g., fish) or a part (e.g., amphibians) of their life cycle and thus require long periods of water storage and inundation. This function has been shown to be critical to the reproductive success of many fish species that either spawn or rear juvenile stages in "off-channel" springbrook habitats (Cavallo 1997).

Characteristics and Processes that Influence the Function. The characteristics and processes that influence the capacity of the floodplain to exchange and store floodwater are related to: (1) the hydrographic regime of the river affecting both surface flooding and subsurface flooding, (2) the geomorphology of the floodplain, and (3) the interconnectivity between the main channel, side channels, and surface and subsurface paleochannels. These characteristics are affected by hydrologic factors subject to climate, watershed characteristics, and conditions in the stream channel. In general, the intensity, duration, and extent of precipitation affect the magnitude of runoff and associated flooding patterns. Watershed characteristics such as size and shape, channel and watershed slopes, drainage density, and the presence of watershed scale retention (e.g., wetlands and lakes) have a pronounced effect on hydrographic patterns (Leopold 1994). Watershed shape affects how quickly surface and subsurface flows reach the floodplain. For example, a round-shaped watershed concentrates

runoff more quickly than an elongated watershed and will tend to have higher peak flows. The higher the drainage density (i.e. the sum of all the channel lengths divided by the watershed area) the faster water is concentrated and flowing within the river channel and thus affecting the height and shape of a rainstorm hydrograph. In general, these climatic and watershed characteristics are the same in a given region and are considered constant for the purposes of rapid assessment. However, site-specific characteristics of the floodplain being assessed can vary and will affect this function.

Depth, frequency, and duration of flooding vary spatially across the floodplain and vary temporally within and between years. Conditions conducive to flooding are dictated, to a large degree, by the nature of the river channel slope, the supply of large sediment (i.e., cobble and gravel) and the hydrographic regime (Church 1993). Thus, the morphology of the stream channel and the morphology of the floodplain and its associated habitats reflect the legacy of historical discharges and sediment loads. Under stable flow and sediment conditions, the river and its floodplain generally reflect a quasi-equilibrium. Alteration to the floodplain or the river channel or the hydrograph (i.e., through watershed disturbance or manipulations) causes instability that results in channel agradation or degradation and a change in depth, frequency and duration of overbank flow events. As the stream channel agrades, the main river channel typically increases in hydraulic radius and raises the frequency and duration of flooding. Conversely, as a river channel degrades, the channel decreases in hydraulic radius, resulting in greater channel depth and decrease in the frequency and duration of flooding. While confined stream reaches often have gradients >2-4 percent, unconfined reaches which characterize the floodplains have slopes <1 percent. For example, the Nyack floodplain on the middle fork of the Flathead River southeast of West Glacier, Montana, and shown in Figure 6, has an elevation gradient of approximately 9 m over a valley distance of ~10 km.

This function is influenced onsite by: (1) the frequency of flooding from the river, first onto the annually scoured flood channel (i.e., exposed riverbed), secondarily into side channels and paleochannels, and finally onto active floodplain terraces, (2) the frequency of subsurface flooding, which is also correlated with the river hydrograph and involves the flow of water through highly porous subsurface cobble and gravel, particularly subsurface paleochannels, and the raising of the floodplain water table, and (3) the maintenance of surface habitat connectivity.

This function is directly influenced by the hydrographic regime of surface water ($V_{SURFREQ}$), the hydrographic regime of groundwater sources of flooding ($V_{SUBFREQ}$), the macrotopographic complexity (V_{MACRO}) that affects the surface connectivity between the river and the floodplain and modifications that may be superimposed on the geomorphology (V_{GEOMOD}) of the floodplain by human activities (e.g., levees, dikes, rip-rap etc.) that prevent the natural movement of the river channel and the processes of cut-and-fill alluviation.

Description of Model Variables.

a. *Frequency of Surface Flooding ($V_{SURFREQ}$).* The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull condition is surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of 10 years). However, the various habitats of a floodplain also exhibit different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel and into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 15). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleochannels flood at a frequency >10 years then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as a 0.0.

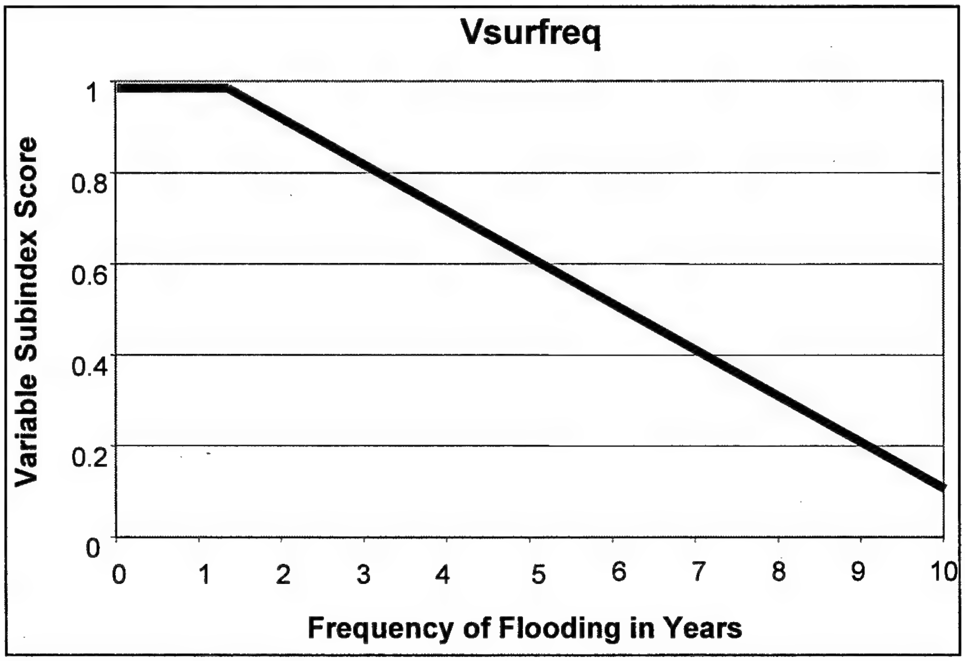


Figure 15. Function 1: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer/cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river

hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8 based on the flood frequency of side and paleochannels but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

b. Frequency of Subsurface Flooding ($V_{SUBFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by extensive subsurface flooding of disconnected side channels, meander scrolls, and fluvial depressions. The subsurface flooding primarily occurs via the preferential flow pathways established by the history of channel avulsion and the creation of paleochannels. Connectivity is so profound among reference standard floodplains that these systems flood virtually every year with the spring snowmelt that characterizes the natural hydrographic regime of the Reference Domain. This variable is scaled at a frequency for subsurface flooding of each year at 1.0 and greater than 5 years as 0.1 (Figure 16). Entrenchment, channelization, and dikes and /or levees that restrict the movement of the main channel may result in loss of stage height during floods and at base flow. The consequence is a reduction in the frequency of subsurface flooding, as well as a rapid dewatering of floodplain wetlands during midsummer months. These floodplains may also lose flooding if subsurface connections are broken or the river bottom becomes armored with fine sediments and entry points into the pathways of preferential flow are sealed. If modification to the floodplain through construction of levees or dikes, degradation of the riverbed, or modification to the hydrologic regime is sufficient to hydrologically disconnect the river from the floodplain via subsurface flooding (e.g., up-stream high-head hydroelectric dam), the assessment team may conclude that subsurface flooding has been eliminated from the river. In such an instance, a variable subindex score of 0.0 is justified.

c. Macrotopographic Complexity (V_{MACRO}). This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools, and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, V_{MACRO} is evaluated at the landscape spatial scale. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff years and thus is integral to the description and characterization of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it is critical to both onsite and offsite effects of modification to the floodplain.

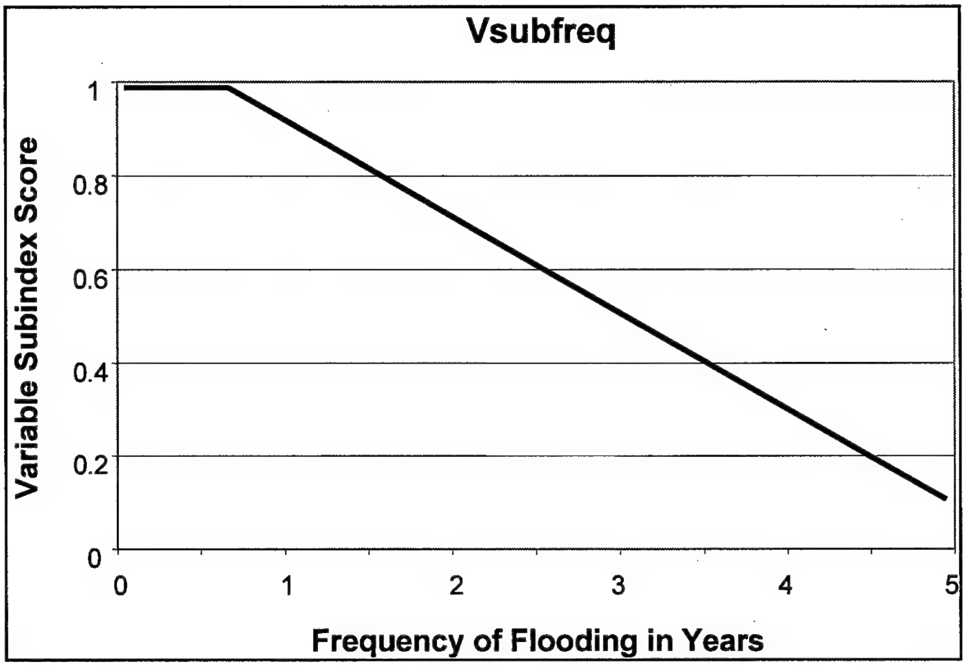


Figure 16. Function 1: Relationship of surface flood recurrence and the corresponding $V_{SUBFREQ}$ Variable Subindex Score

The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, evaluation should be based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photos.

This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 8).

d. *Geomorphic Modification (V_{GEOMOD}).* This variable represents the anthropogenic modification of the floodplain's geomorphic properties through modifications to control the river channel. Examples of geomorphic modification commonly practiced are riprap, revetment, dikes, levees, bridge approaches, and roadbeds. Each of these man-made structures function to preclude the movement of water from the channel onto the floodplain. Geomorphic modification on riverine floodplains that directly affects riparian wetlands has been done in the past to confine the river to protect property for domestic, commercial, or agricultural purposes.

Table 8
Function 1: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

The modification to the floodplain is geomorphic in nature, but directly affects hydrologic properties. Reveting, filling, mining, dredging, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated for each cover type polygon described within an Assessment Area. Offsite effects of geomorphic modifications may be extensive. The assessment team is advised to proceed cautiously in determining the scope of this variable, both within and adjacent to the Assessment Area. Table 9 presents a series of approximate ranges of the various types and extent of geomorphic modification between the main river channel, paleochannels and floodplain terraces that commonly occur under different levels of impact.

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{SUBFREQ} + V_{MACRO}}{3}\right) \times V_{GEOMOD}\right]^{1/2}$$

In the model equation the capacity of the wetland to store surface water depends on the following factors: (1) the frequency and duration of surficial flooding, (2) the frequency and duration of subsurface flooding through the rise in the groundwater table, (3) the macrotopographic complexity of the floodplain facilitating the free flow of water into wetland habitats on the floodplain surface, and (4) the effect of geomorphic modification to the river channel or other surface features on the floodplain surface that directly or indirectly affects alluvial processes.

Table 9
Function 1: Calculation Table of Variable Subindex Scores Based on Unaltered and Altered Geomorphic Conditions on the Floodplain

Description	Score
No geomorphic modifications (e.g., dikes, levees, riprap, bridge approaches, road beds, etc.) made to contemporary (Holocene) floodplain surface.	1.0
Few changes to the floodplain surface with little impact on flooding. Changes restricted to < 1 m in elevation and only for farm roads or bridges with culverts maintained. Geomorphic modifications do however result in minor change in cut-and-fill alluviation.	0.75
Modification to the floodplain surface < 1 m in elevation. Riverbank with control structures (e.g., riprap) < 10% of river length along LAA. Geomorphic modifications result in measurable change in cut-and-fill alluviation.	0.5
Multiple geomorphic modifications to the floodplain surface to control flood energy, often with bank control structures, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in significant reduction in cut-and-fill alluviation.	0.25
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure or constructed to prevent channel avulsion, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in termination of cut-and-fill alluviation.	0.1
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure preventing channel avulsion and also preventing flow access via culverts to backwater and side channels	0

In the first part of the equation, $V_{SURFREQ}$, $V_{SUBFREQ}$, and V_{MACRO} are direct measures of the interaction between the river and its floodplain to dynamically store flood waters. The equation expresses these three variables as arithmetic means. Therefore all three variables would have to equal zero before this portion of the equation equals zero. Such a condition would be highly unusual, but could be possible where a floodplain has been hydrologically disconnected from the river.

In the second part of the equation, V_{GEOMOD} reflects anthropogenic modifications to the geomorphology that result in change in water regime for the floodplain. The geomorphic modifications may be due to river edge or bank structures or, more commonly, various forms of revetments to prevent flooding or change in the river channel. This variable is calculated as a geometric mean for the equation since if any particular modification variable or flooding variable no longer occurs then it follows that this function will also no longer occur.

Function 2: Nutrient Cycling

Definition. Nutrient cycling is defined as the acquisition of inorganic forms of essential nutrients, converting them into organic forms, generally resulting in plant growth, and then through various microbially mediated metabolic and biogeochemical processes converting them back into inorganic forms. The two nutrients that are of greatest interest, as well as of greatest concern as sources of eutrophication and nutrient enrichment, are phosphorus and nitrogen. Phosphorus comes from a variety of sources, including parent geologic material, as dissolved

or particulate forms in wet and dry precipitation, and from anthropogenic sources of pollution. Nitrogen comes to the floodplain from a variety of sources as well; however, unlike phosphorus, nitrogen is present in the atmosphere as a gas (N_2), which can be fixed by microbes. Nitrogen is most readily used and cycled in a reduced condition, but it is also absorbed and used as nitrate. The vast majority of the world's ecosystems cycle nutrients (Molles et al. 1998). However, unique to riverine systems are unidirectional flow and the process by which nutrient cycling becomes nutrient spiraling (Webster, Benfield, and Cairns 1979). Floodplains and their associated riverine wetlands apparently cycle nutrients in such a way that the efficiency with which these limiting elements are utilized increases, resulting in high productivity, reduction in dissolved nutrients, and maintenance/improvement of water quality.

Potential independent, quantitative measures of this function include: (1) nutrient flux onto, through, and from the floodplain, (2) nutrient uptake on the floodplain by organic and inorganic processes, (3) nutrient generation (particularly N) on the floodplain, and (4) long-term nutrient storage.

Rationale for Selecting the Function. Nutrient cycling is a fundamental function performed by all ecosystems, but it is a particularly important feature of riverine floodplains (Fisher et al. 1998, Ellis et al. 1998) Floodplains and their associated wetlands are highly productive components of the landscape. Primary production of plants, from trees on floodplain terrace surfaces to algae in the river and springbrooks, is significantly enhanced by the supply of water and the conversion of nutrients from organic forms to inorganic, highly available forms. In short, nutrient cycling is essential to the long-term maintenance of floodplain productivity and species diversity.

The ability of a river floodplain and its associated wetlands to perform this function is dependent upon the transfer of elements and materials between trophic levels, the rates of decomposition, and the flux of materials in and out of the floodplain. A change in the ability of one trophic level to transform materials will result in changes in the transformation of materials in other trophic levels (Carpenter 1988). Riparian wetlands distributed across the floodplain surface function as ecotones between terrestrial and aquatic environments (Naiman et al. 1988). As areas of terrestrial and aquatic interfaces, floodplains are particularly subject to anthropogenic change as cultural development (e.g., transportation corridors, levees, dikes, riprap) constrains the dynamic relationship between rivers and their floodplains (Gregory et al. 1991). These changes may greatly affect the way rivers and their floodplain-wetland complexes perform this function.

Characteristics and Processes that Influence the Function. Probably the most familiar nutrient cycling or biogeochemical is cycling through plants and the processes of photosynthesis and respiration. River floodplains and their associated wetlands in the northern Rocky Mountains are extremely diverse and complex. Floodplain surfaces have a variety of plants that may or may not be hydrophytic. In permanently submerged habitat, hydrophytes, which are uniquely adapted to living in water or wet soil environments, dominate the vegetative community. Physiological adaptations in leaves, stems, and roots allow for greater gas exchange and permit respiration to take place and allow the plant to

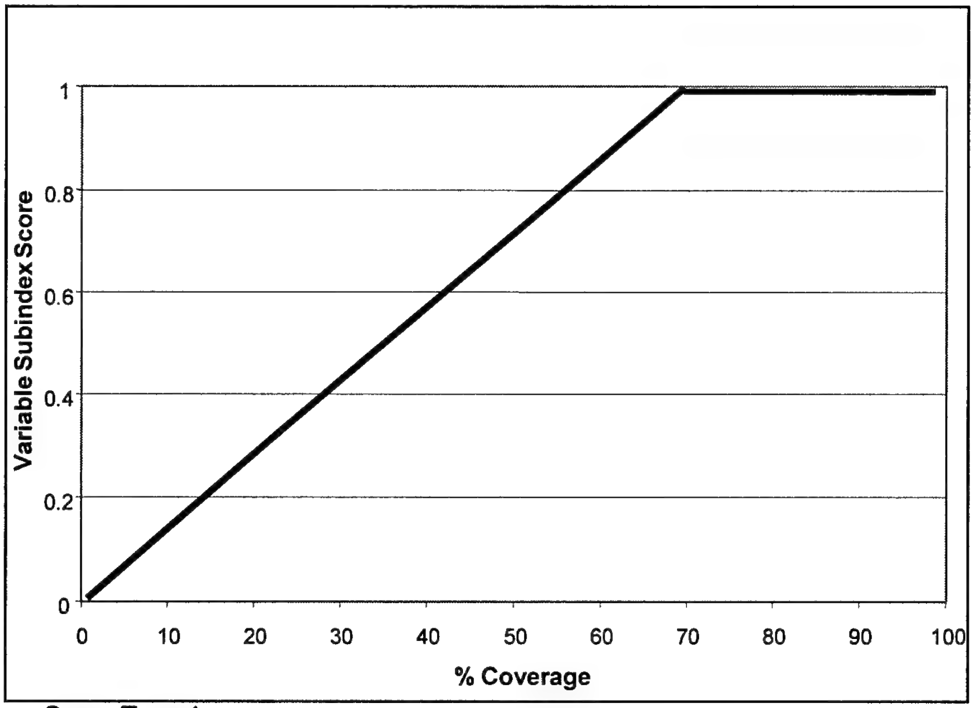
harvest the stored chemical energy it has produced through photosynthesis. Although there is no clear starting or ending points for nutrient cycling, it can be argued that it is the interrelationship between fluvial geomorphology, river power, and the temporal presence of water on the floodplain-wetland complex that determines the characteristic plant community. In turn, it is the maintenance of the characteristic primary productivity of the plant community that sets the stage for all subsequent transformation of energy and materials at each trophic level on the floodplain surface. Likewise, the growth and metabolic activities of the plant communities on the floodplain surfaces most probably have a significant influence on subsurface processes which affect the productivity of both the river and the floodplain. It follows that alterations to hydrologic inputs, outputs, storage, and/or changes to the characteristic plant community will directly affect the way in which the floodplain-wetland complex can perform the function of nutrient cycling.

The ideal approach for assessing nutrient cycling on the floodplain-wetland complex would be to measure the rate at which elements and materials are transferred and transformed between and within each trophic level over several years. However, the time and effort required to make these measurements are well beyond a rapid assessment procedure. However, reference data suggest that land-use practices and current treatments have great effect on the characteristic plant community structure (species composition and coverage), diversity, and primary productivity. Soil profile characteristics, particularly the depth and color of the O- and A-horizons, are indicators of long-term nutrient supply and a characteristic decomposer community. Also, the presence of a characteristic native plant community is essential to this process occurring at reference standard rates. It is assumed that measurements of these characteristics reflect the level of nutrient cycling taking place across the floodplain-wetland complex. Comparison of these data, between a target wetland and the characteristics of reference standard wetlands, indicates changes in the level of nutrient cycling.

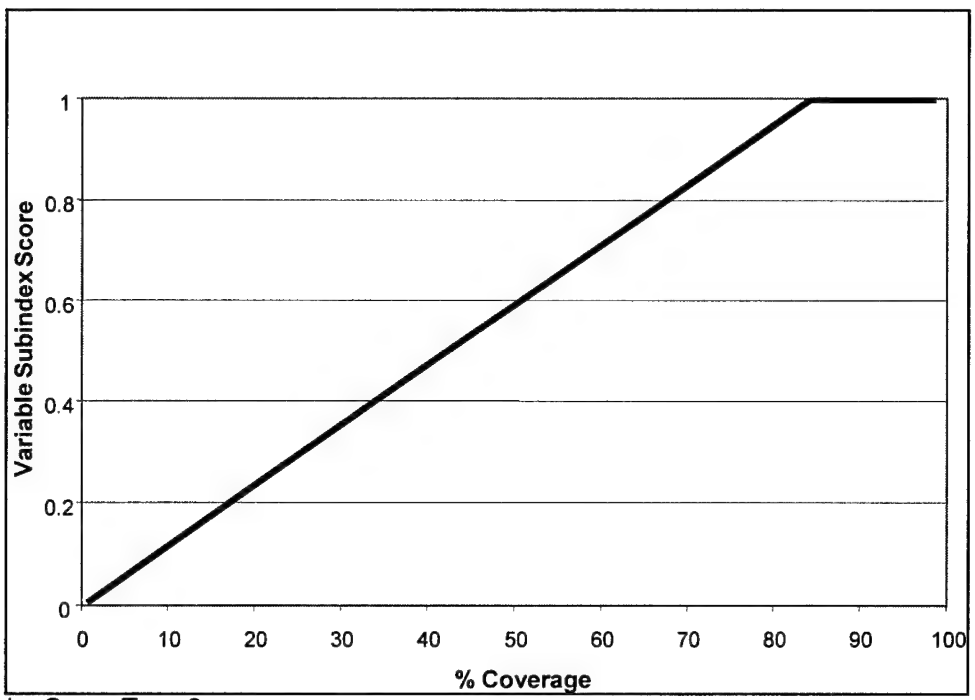
This function is directly influenced by the floodplain vegetation characterized by the variables (V_{HERB}), (V_{SHRUB}), and (V_{DTREE}), the complexity of the floodplain mosaic ($V_{COMPLEX}$), which provides a proportional setting for the function, and the variable that reflects organic matter decomposition ($V_{ORGDECOMP}$).

Description of Model Variables.

a. Herbaceous Plant Coverage (V_{HERB}). This variable represents the percent coverage of herbaceous plants per unit area across the floodplain by cover type. The herbaceous layer is defined as all herbaceous grasses and forbes that do not have woody stems. The herbaceous coverage changes between cover types and is one of the first variables to respond to human disturbance on the floodplain. Herbaceous coverage is measured as the percent coverage within a 1-m by 1-m plot. If the shrub coverage is being estimated within Cover Types 1-4 (tree- and shrub-dominated cover types) then the herbaceous coverage should be estimated within the larger plots. Figure 17 presents the density of herbs expressed as percent coverage and the corresponding Variable Subindex Scores for each of the six cover types that are evaluated for this variable.

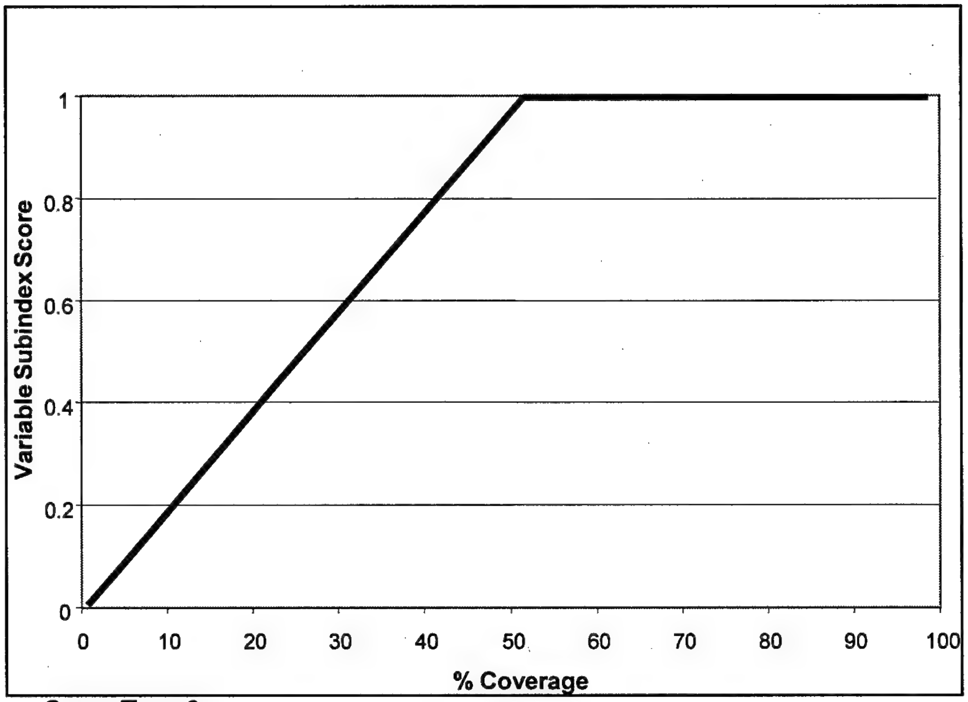


a. Cover Type 1

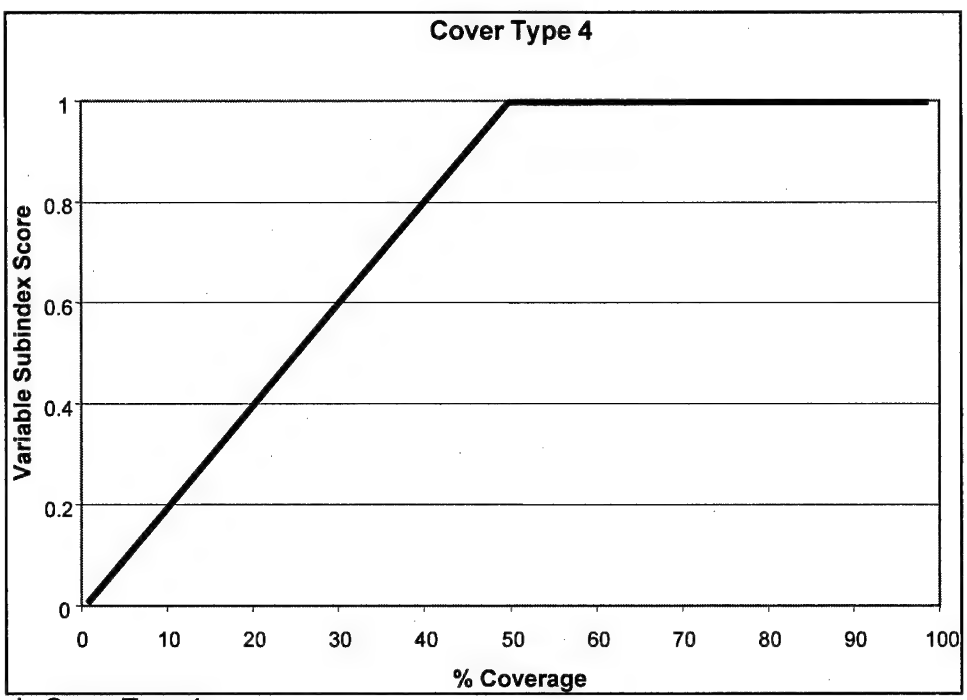


b. Cover Type 2

Figure 17. Function 2: Percent coverage of the herbaceous layer of plants and corresponding Variable Subindex Scores for Cover Types 1-6 (Sheet 1 of 3)

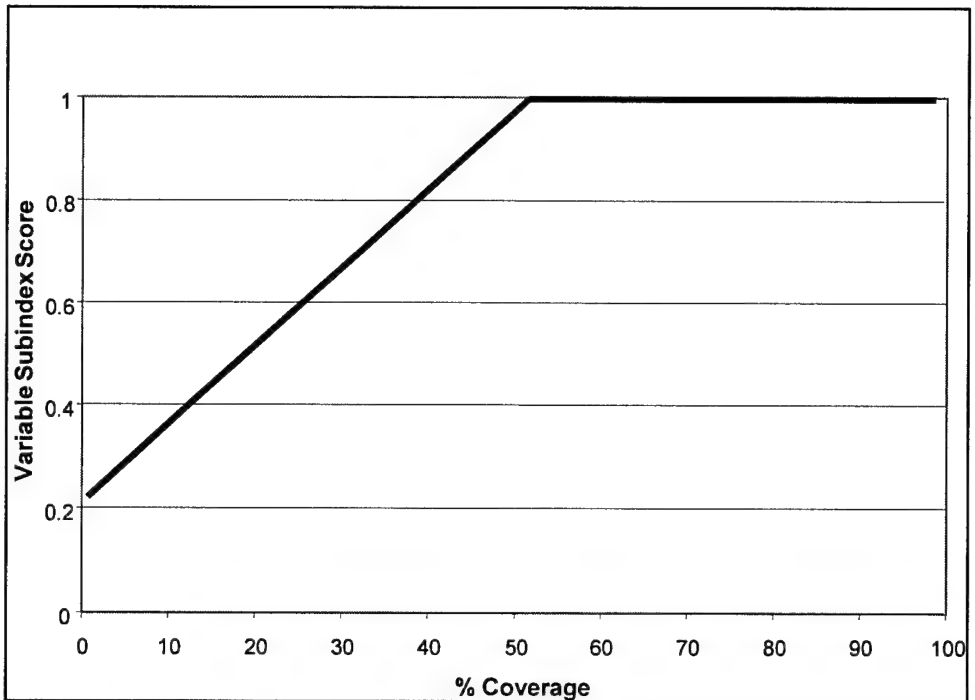


c. Cover Type 3

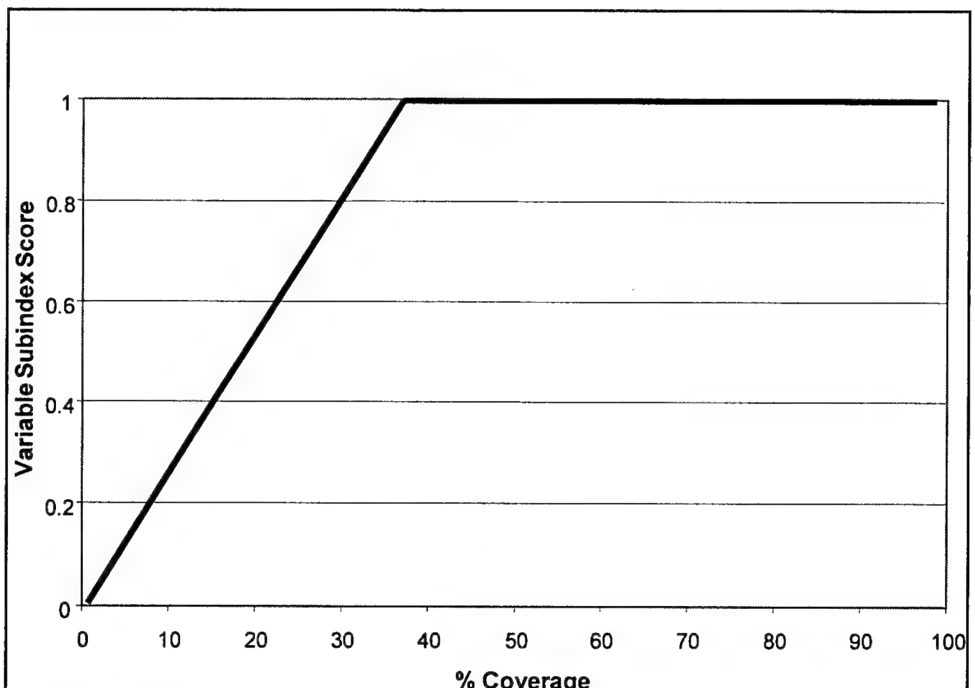


d. Cover Type 4

Figure 17. (Sheet 2 of 3)



e. Cover Type 5

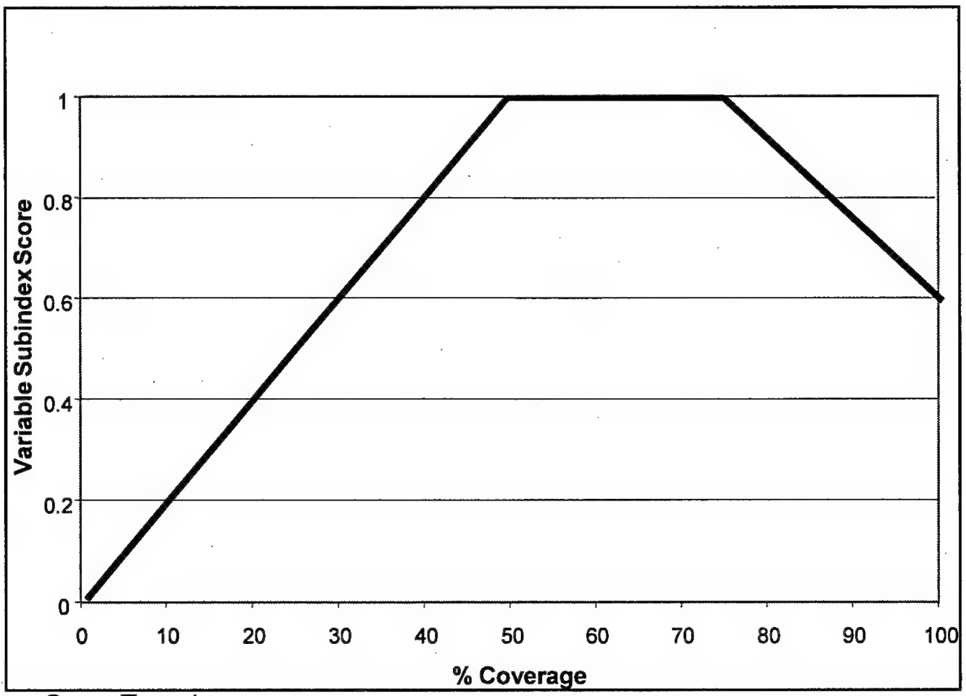


f. Cover Type 6

Figure 17. (Sheet 3 of 3)

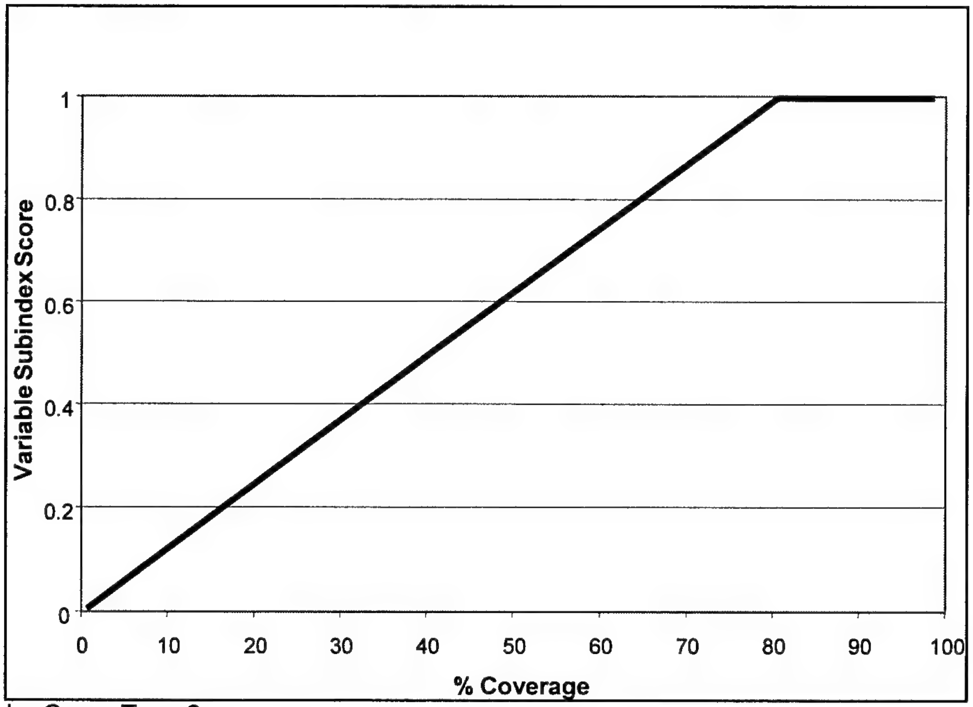
b. Pole Cottonwood, Willow, Shrub, and Sapling Coverage (V_{SHRUB}). This variable represents the percent coverage of shrubs and saplings per unit area across the forested and shrub covered floodplain. Shrubs and saplings are defined as woody stems <6 m in height and <10 cm dbh. The shrub and sapling coverage changes between cover types. In the context of this variable, pole cottonwood, willow, and shrub density is measured as a function of percent coverage rather than stem density because of the high variability among species.

Shrub coverage is measured as the percent coverage within a 5- by 5-m plot. If the shrub coverage is being estimated within Cover Types 1 and 2 (tree-dominated cover types) then the plot should be taken as one of the quarter sections of the tree density plots. Cover Type 3 and 4 plots are selected independently since the pole cottonwoods, saplings, and shrubs are the dominant woody species. It is common to encounter very narrow Cover Type 4 and 5 polygons as a result of fluvial processes on the floodplain and the subtle differences in elevation. When this occurs, plots should be extended in length and narrowed in width, yet a 25-m^2 plot should remain the standard plot size. Figure 18 presents the density of shrubs and saplings and the corresponding Variable Subindex Scores for each of the five cover types commonly having a major shrub component of the vegetation.

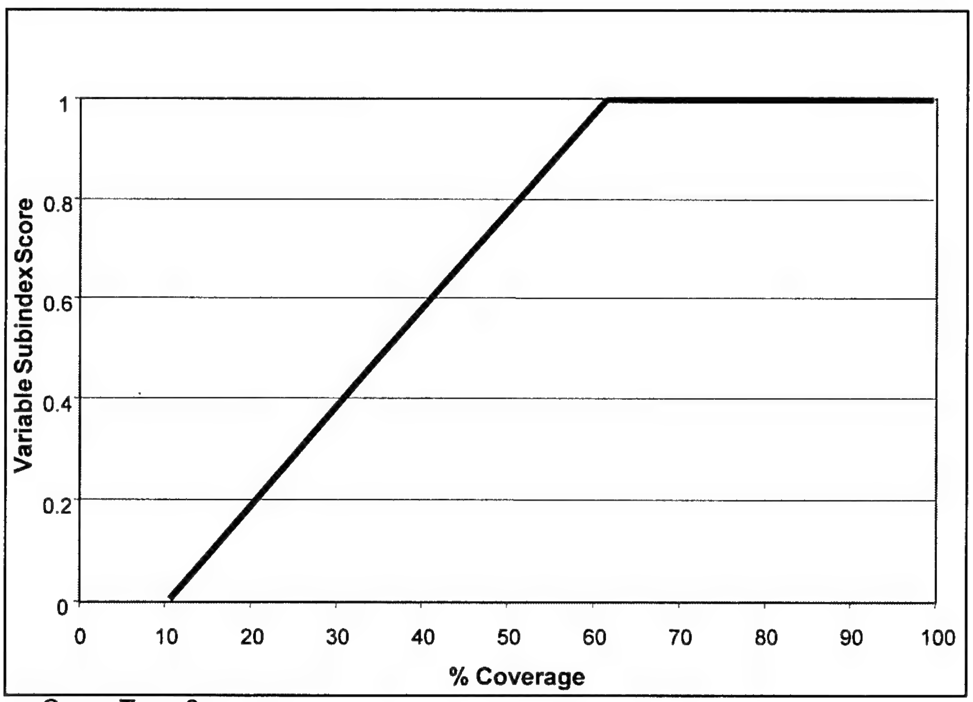


a. Cover Type 1

Figure 18. Function 2: Percent coverage of the shrub layer of plants and corresponding Variable Subindex Scores for Cover Types 1-5 (Sheet 1 of 3)

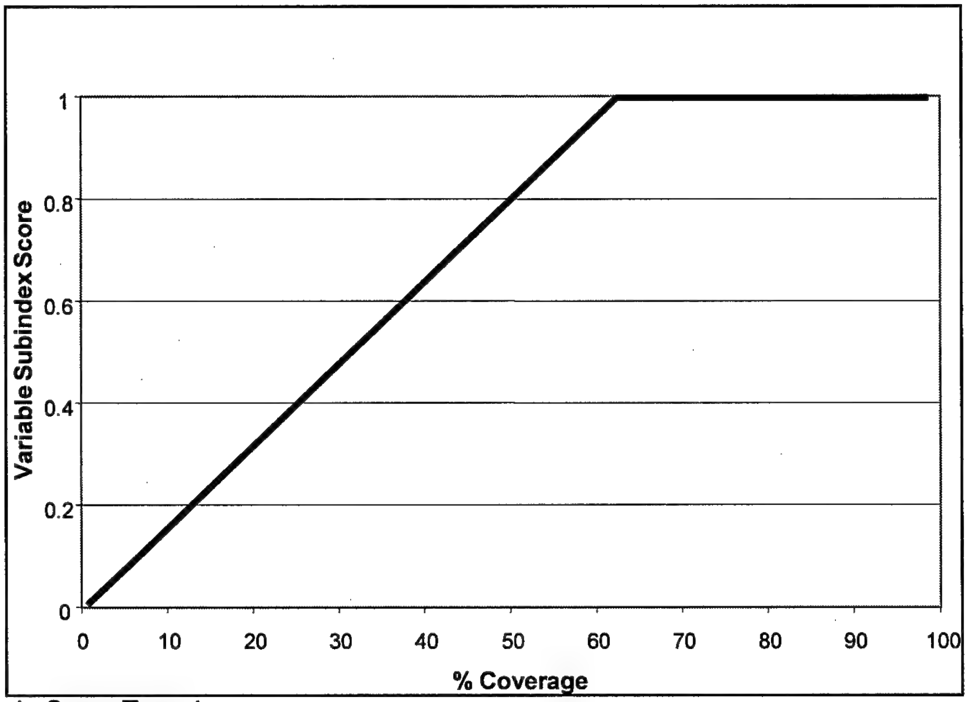


b. Cover Type 2

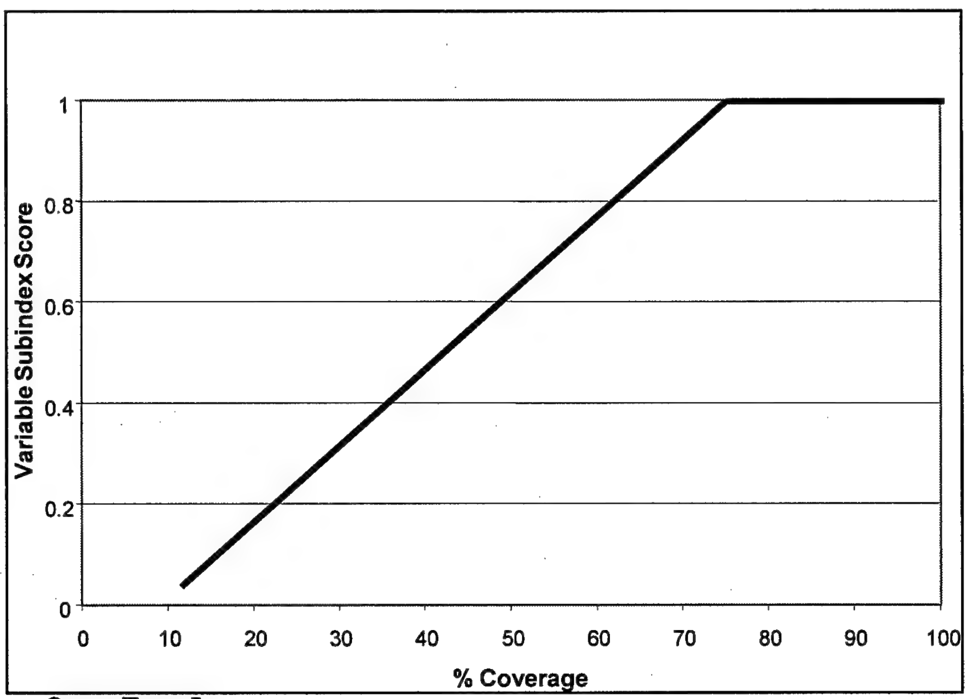


c. Cover Type 3

Figure 18. (Sheet 2 of 3)



d. Cover Type 4



e. Cover Type 5

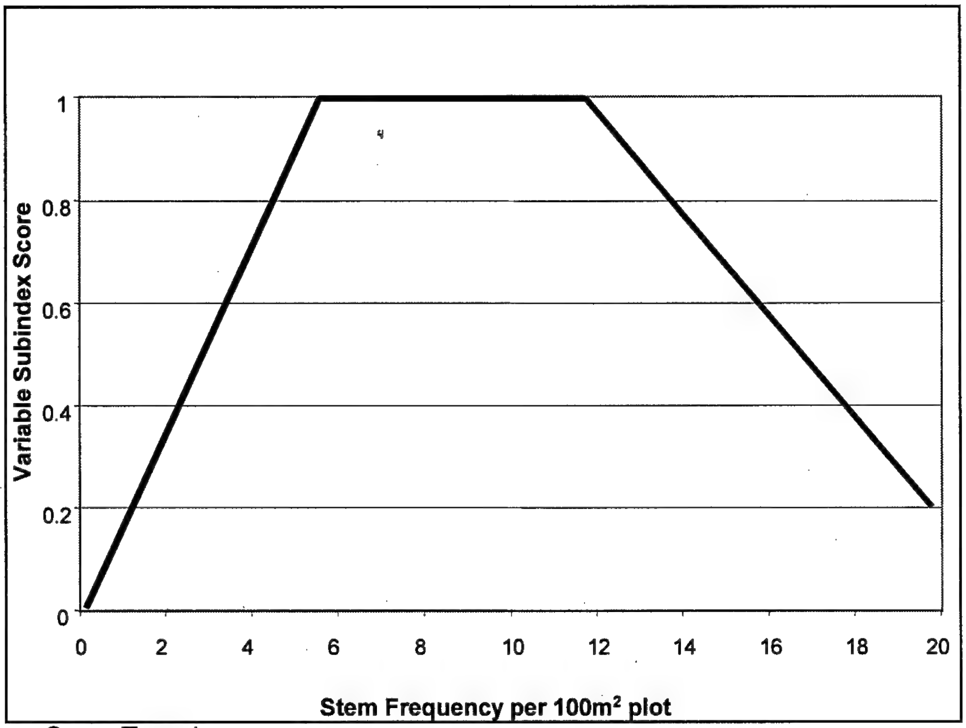
Figure 18. (Sheet 3 of 3)

c. *Tree Density (V_{DTREE}).* This variable represents the number of trees per unit area across the forested cover types of the riparian floodplain wetlands. Trees are defined as woody stems $\geq$6 m in height or $\geq$10 cm dbh. In most forested systems, tree stem density and basal area increase rapidly during the early successional phases. This is also true in the northern Rocky Mountain floodplain systems. Thereafter, tree density decreases and basal area increases as the forest reaches mature steady-state conditions (Spurr and Barnes 1980). In the context of this function, tree density serves as an indicator of plant community structure.

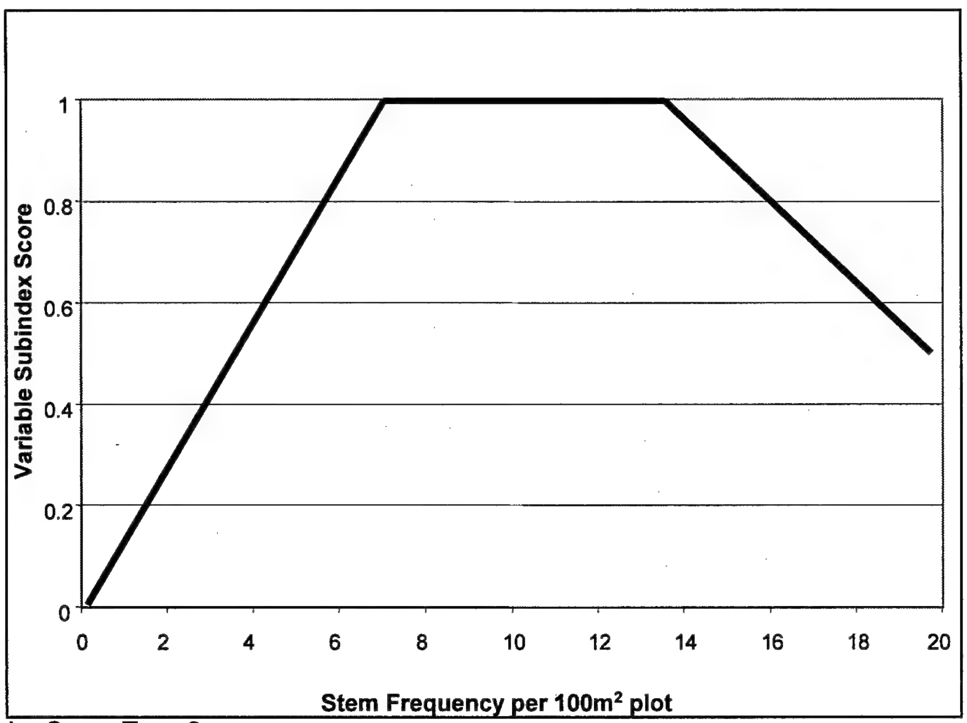
This variable is measured by averaging the number of tree stems in a 10- by 10-m plot. If the density is low, increase the size of the plot, but relativize the data to number per 100-m^2. The number of sample plots required to adequately characterize the area being assessed will depend on its size and heterogeneity of the forest within the cover type being evaluated; however, sample at least three plots in any one stand or floodplain polygon, more if heterogeneity is high. Average the results from all plots. The section on Assessment Protocols provides guidance for determining the number and layout of sample points and sampling units. Figure 19 presents the density of trees and the corresponding Variable Subindex Scores for the two cover types dominated by mature forest canopy trees.

d. *Proportionality of Landscape Features ($V_{COMPLEX}$).* This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. See the descriptions given in Assessment Protocols (Chapter 5) for determining the appropriate size or area of floodplain to be assessed.

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 10 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/floodplain complex can be described by a combination conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and that often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and cover 15-25 percent of the surface area. Likewise the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times



a. Cover Type 1



b. Cover Type 2

Figure 19. Function 2: Tree stem density and corresponding Variable Subindex Scores for Cover Types 1 and 2

Table 10
Function 2: Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect the Reference Standard Condition as a Condition that has been Significantly Impacted with Loss of Floodplain Complexity

	Variable Subindex Score								
Cover Type	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

e. *Decomposition of Organic Matter* ($V_{ORGDECOMP}$). This variable is an indicator of organic matter decomposition and thus nutrient cycling in the surface soils of the floodplain-wetland complex. The soil O-horizon is composed largely of organic materials derived from dead plant tissue. The plant tissues and residues at various stages of decomposition are both a nutrient store and source for the floodplain. Departures in the depth of the O-horizon from reference standards are indicators of too little or too much organic addition or too fast or too slow a rate of decomposition.

This variable focuses on both the O-horizon and the Surface Mineral Soil Horizon, which may be either an A-horizon or E-horizon. Both the A- and E-horizons are characterized by the accumulation of humus within the mineral soil. Humus is black in color, highly decomposed and is naturally colloidal (i.e., has a small particle size, large surface area, and net negative charge). Its ability to hold nutrients is greater than any other soil constituent. Because the surfaces of these floodplains are relatively young (many <200 years), soils are often poorly developed and in the process of developing; thus many of the mineral soils are present as an E-horizon rather than the more developed A-horizon. Therefore throughout this document the A-horizon and E-horizon are combined into a single category and referred to as the Surface Mineral Soil Horizon (SMS-horizon). The depth and color of the SMS-horizon is an index of the soil's ability to store nutrients for plant availability. Departures from reference standards are indicators of changes in long-term organic matter inputs. A thin, lightly colored SMS-horizon may be the result of lowered productivity caused by some form of human disturbance or management.

An SMS-horizon having a thickness greater than Reference Standard is often the result of accelerated deposition of fine sediments carried by the river and deposited on the floodplain. $V_{ORGDECOMP}$ is calculated as an Organic Matter Decomposition Factor (OMDF) based on the depth of the O-horizon, the depth of the SMS-horizon, and the Soil Color Value (from Munsell Soil Chart) of the SMS-horizon. The OMDF is calculated as:

$$OMDF = \left[(OHorizonDepth) + \left(\frac{SMSHorizonDepth}{SoilColorValue} \right) \right]$$

The Variable Subindex Score for $V_{ORGDECOMP}$ is determined for different floodplain cover types. Correlation between OMDF and the Variable Subindex Scores are illustrated in Figure 20a for Cover Types 1 and 2 soils and in Figure 20b for Cover Types 3, 4, 5, and 6 soils.

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

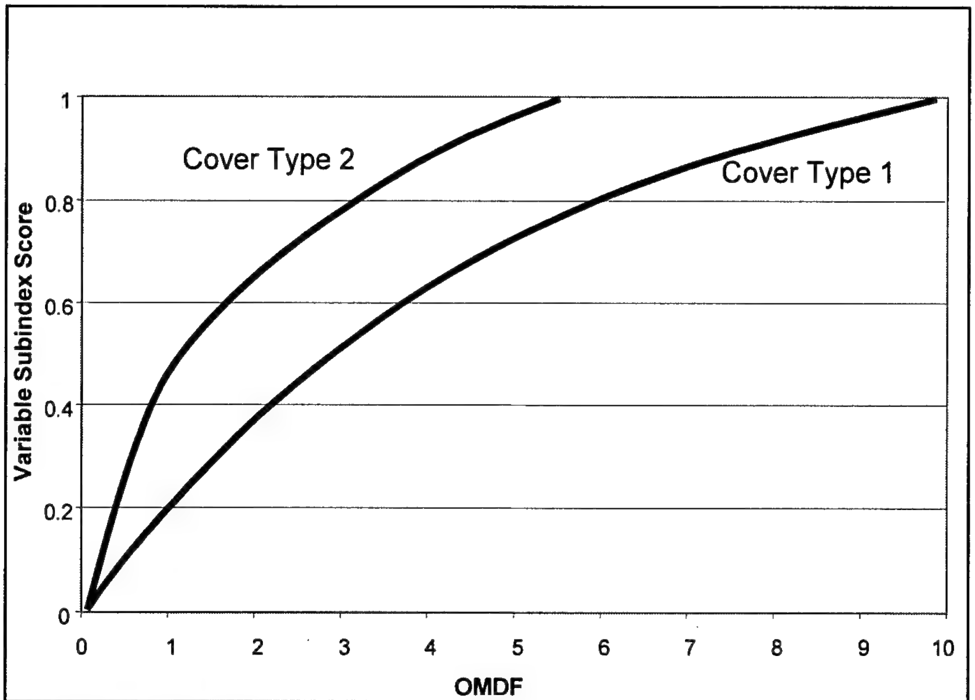
$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE}}{3} \right) \times V_{COMPLEX} \times V_{ORGDECOMP} \right]^{1/3}$$

In the model equation, nutrient cycling depends on: (1) the proportional scores for herbaceous plant coverage, shrub coverage, and tree density, (2) the mosaic or landscape complexity of features on the floodplain, and (3) the organic matter decomposition. In the first part of the equation, V_{HERB}, V_{SHRUB}, and V_{DTREE} are direct measures of vegetation and its contribution to appropriate levels of nutrient cycling. The equation expresses these three variables as arithmetic means. In the second part of the equation, $V_{COMPLEX}$ reflects the complexity of the floodplain surfaces and their relative proportions across the floodplain. Organic matter decomposition constitutes the third portion of this equation as an indicator of the decomposition process in the nutrient cycle. Each of these three parts are placed within the context of the geometric mean.

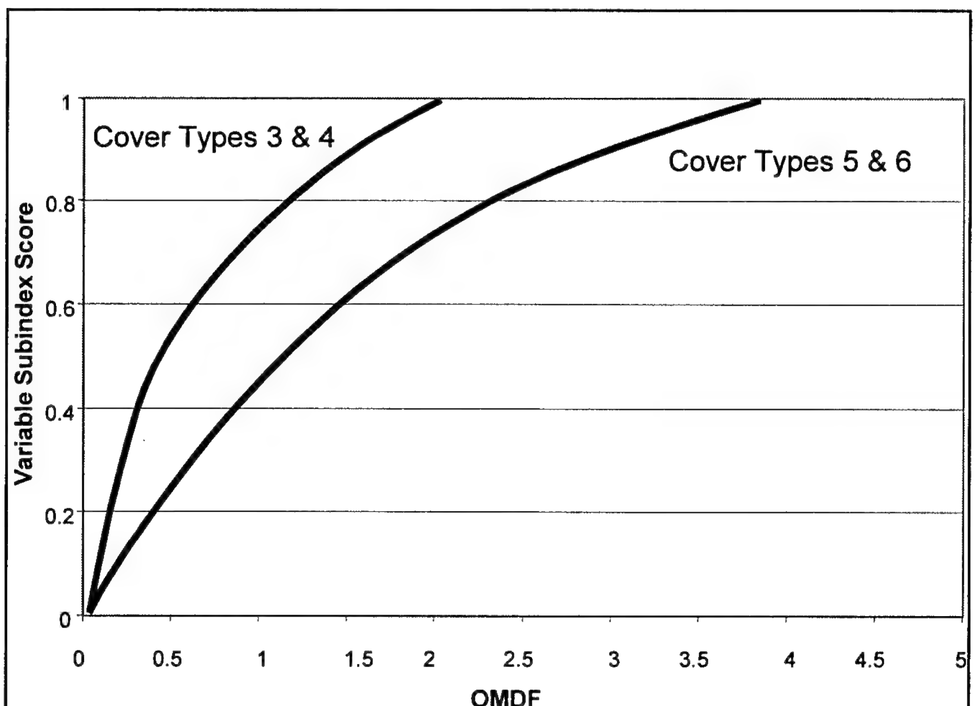
Function 3: Retention of Organic and Inorganic Particles

Definition. Retention of Organic and Inorganic Particles is defined as the ability of the riverine floodplain-riparian-wetland mosaic to capture and temporarily (e.g., years, decades, and centuries) retain both organic and inorganic particles. These particles range in size from cobble to colloidal inorganics and from trees to very fine seston organics. These materials are imported to the floodplain from other sources in the watershed or may originate on the floodplain.

A potential independent measure of this function is developing a sediment budget and quantifying inorganic sediments and organic matter accumulated per unit area during a specified period of time (e.g., $g/m^2/yr$).



a. Cover Types 1 and 2



b. Cover Types 3, 4, 5, and 6

Figure 20. Function 3: Correlation between $V_{ORGDECOMP}$ OMDF and the Variable Subindex Score for Cover Types 1-6

Rationale for Selecting the Function. Generally throughout the northern Rocky Mountain reference domain, river gradients and landforms alternate between confined and unconfined reaches (Stanford and Ward 1993). Confined reaches have a relatively high gradient while unconfined reaches tend to have a lower gradient (Stanford 1998). The lower-gradient unconfined reaches are characterized by bed material retention as well as the accumulation of organic materials ranging from large woody debris to fine sestonic matter that settles onto the floodplain surfaces during flooding events (Lamberti and Gregory 1996, Wallace and Grubaugh 1996).

The process of particle retention is integral to the physical development of the floodplain. Bed sediments may be deep or shallow, highly porous or with fine sediments restricting groundwater flow. The expansive deposits that so characterize floodplains and their associated wetlands are largely a function of the balance between stream power and the supply of sediments (Church 1992). High sediment supplies result in increased rates of cut and fill alluviation and avulsion, which directly affect the frequency and character of zones of preferential flow, and the capacity of hydraulic conductivity (Stanford 1998). In zones of preferential flow, hydraulic conductivity is measured in cm/sec rather than mm/day as is customary in groundwaters (Baxter and Hauer 2000).

Characteristics and Processes that Influence the Function. This function is primarily influenced by characteristics and processes of the river and its floodplain/wetlands to, first, transport water, bed sediments, and organic particles and, secondarily, to retain those materials in the aggraded sections of the river (i.e. floodplains). River morphology reflects the concentration and size of the sediments moving down the channel. When river sediments are predominantly fine-grained (i.e., silts and sands), materials are largely carried in suspension, and much of the sediment load is deposited in depositional zones on floodplains during floods. This leads to the building of relatively high, fine-grained, and cohesive banks and a relatively narrow, single-threaded channel that meanders across the floodplain. However, when river sediments are composed primarily of coarse materials (i.e., gravel and cobble), these materials are transported on or near the bed-surface and deposited in bars, which fill the channel and deflect the river in irregular patterns (Church 1992). Depending on the supply of sediments, coarse-grained river systems are characteristically wide and shallow with irregular, braided channels with noncohesive banks formed from the coarse materials. The dynamic deposition and reworking of these porous bed sediments by fluvial processes are viewed within the context of contemporary river ecology as a dynamic mosaic of fully or partially saturated habitats. These habitats exist in a three-dimensional state in which interconnected patches exchange materials horizontally and vertically (Stanford 1998). In the reference standard condition, flooding occurs annually within the channel and through side channels and surface paleochannels. During higher-stage floods, with recurrence intervals of ~10 years, higher surfaces are also incorporated in the flooding event.

This function is directly influenced by the hydrographic regime ($V_{SURFREQ}$), the complexity of the floodplain mosaic ($V_{COMPLEX}$), the macrotopographic complexity (V_{MACRO}) that affects the surface connectivity between the river and the floodplain, and modifications that may be superimposed on the

geomorphology (V_{GEOMOD}) of the floodplain by human activities (e.g., levees, dikes, riprap etc.). These various influences on the floodplain dynamics affect the rates of sediment accumulation (both organic and inorganic) across the floodplain. This is also reflected in the rate of accumulation of large wood debris (V_{LWD}) along the exposed river gravel-bars.

Description of Model Variables.

a. Frequency of Surface Flooding ($V_{SURFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull, condition is having surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of 10 years). However, the various habitats of a floodplain also exhibit different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel and into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 21). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleochannels flood at a frequency >10 years, then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as a 0.0.

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8 based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

b. Proportionality of Landscape Features ($V_{COMPLEX}$). This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale,

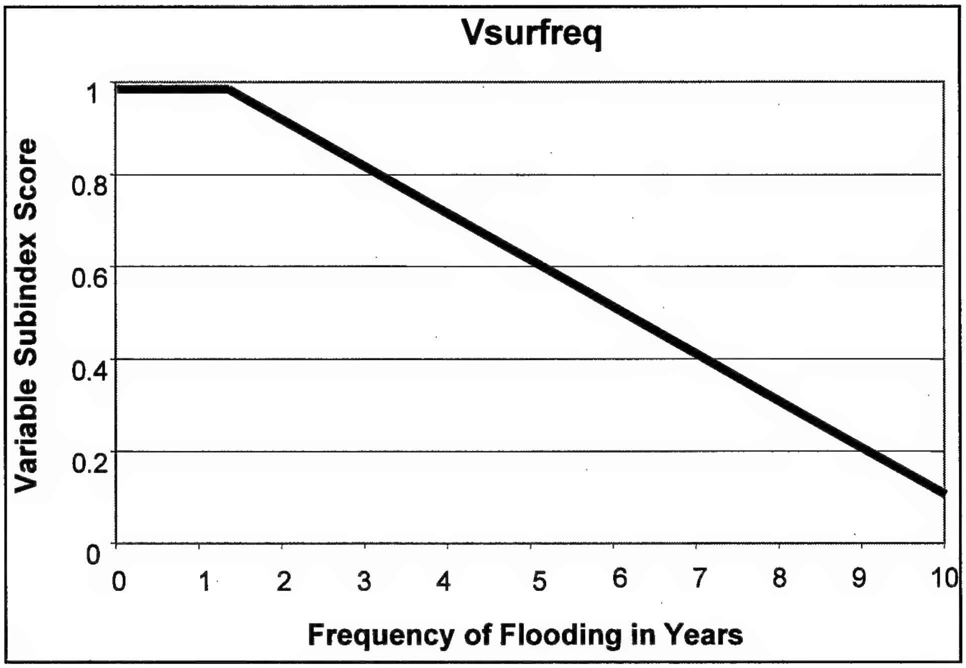


Figure 21. Function 3: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

by its very nature it extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. Descriptions are given in Assessment Protocols (Chapter 5) for determining the appropriate size or area of floodplain to be assessed.

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 11 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/floodplain complex can be described by a combination of conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and cover 15-25 percent of the surface area. Likewise, the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

Table 11 **Function 3: Range of Percentages for the Various Cover Types Corresponding to the Variable Subindex Scores for the Variable $V_{COMPLEX}$**									
	Variable Subindex Score								
Cover Type	**1.0**	**1.0**	**0.8**	**0.7**	**0.5**	**0.4**	**0.2**	**0.1**	**0.0**
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

c. *Macrotopographic Complexity (V_{MACRO}).* This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, Macrotopographic (V_{MACRO}) Complexity is evaluated at the landscape spatial scale. Macrotopographic complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff years, and thus is integral to the description and characterization of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it is critical to both onsite and offsite effects of modification to the floodplain.

The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, it should be evaluated based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photos. This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 12).

d. *Large Wood Debris (V_{LWD}).* Large Wood Debris (LWD) plays an important role in the structure and function of alluvial floodplains. LWD provides surface heterogeneity in the dissipation of energy during floods affecting the deposition of organic and inorganic sediments. LWD also plays a critical role in the development of macrotopographic relief. This development occurs primarily via scour around LWD and root wads during floods. LWD accumulates on gravel bars of the flooded main channel and may remain as aggregates of logjams on abandoned channels following avulsion. LWD is most prevalent in Cover Type 7, and the focus of its quantification is centered in this cover type.

Table 12
Function 3: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

LWD is defined as wood >10 cm in diameter and length >1 m. It is quantified by measuring the frequency of LWD pieces along a 50-m transect 10 m wide. Frequency is quantified as a simple numeric count and scored based on the regression illustrated in Figure 22.

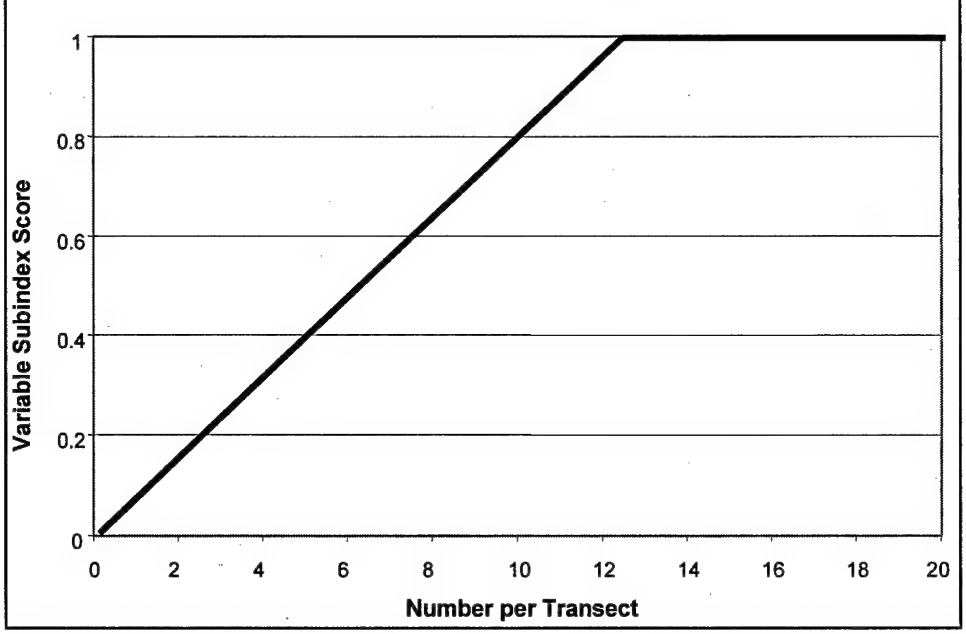


Figure 22. Function 3: Large Wood Debris frequency per transect and corresponding Variable Subindex Score

e. *Geomorphic Modification (V_{GEOMOD}).* This variable represents the anthropogenic modification of the floodplain's geomorphic properties through modifications to control the river channel. Examples of geomorphic modification commonly practiced are riprap, revetment, dikes, levees, bridge approaches, and road beds. Each of these man-made structures function to preclude the movement of water from the channel onto the floodplain. Geomorphic modification on riverine floodplains that directly affect riparian wetlands has been used in the past to confine the river to protect property for domestic, commercial, or agricultural purposes.

The modification to the floodplain is geomorphic in nature, but directly affects hydrologic properties. Revetment, filling, dredging, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated for each cover type polygon described within an Assessment Area. Offsite effects of geomorphic modifications may be extensive. The Assessment Team is advised to proceed cautiously in determining the scope of this variable, both within and adjacent to the Assessment Area. Table 13 presents a series of approximate ranges of the various types and extent of geomorphic modification between the main river channel, paleochannels, and floodplain that commonly occur under different levels of impact.

Table 13
Function 3: Calculation Table of Variable Subindex Scores Based on Unaltered and Altered Geomorphic Conditions on the Floodplain

Description	Score
No geomorphic modifications (e.g., dikes, levees, riprap, bridge approaches, road beds, etc.) made to contemporary (Holocene) floodplain surface.	1.0
Few changes to the floodplain surface with little impact on flooding. Changes restricted to < 1 m in elevation and only for farm roads or bridges with culverts maintained. Geomorphic modifications do however result in minor change in cut-and-fill alluviation.	0.75
Modification to the floodplain surface < 1 m in elevation. Riverbank with control structures (e.g., riprap) < 10% of river length along LAA. Geomorphic modifications result in measurable change in cut-and-fill alluviation.	0.5
Multiple geomorphic modifications to the floodplain surface to control flood energy, often with bank control structures, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in significant reduction in cut-and-fill alluviation.	0.25
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure or constructed to prevent channel avulsion, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in termination of cut-and-fill alluviation.	0.1
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure preventing channel avulsion and also preventing flow access via culverts to backwater and side channels	0

Functional Capacity Index. The assessment model for calculating the functional capacity index is:

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{MACRO} + V_{COMPLEX} + V_{LWD}}{4} \right) \times V_{GEOMOD} \right]^{1/2}$$

In the model equation, retention of organic and inorganic particles depends on the following factors: (1) the frequency of surface flooding, (2) the macro-topographic relief of the floodplain, (3) the proportionality of the floodplain/wetland complex, (4) the large wood debris, and (5) any geomorphic modifications to the floodplain by human disturbance. In the first part of the equation, $V_{SURFREQ}$, V_{MACRO}, and $V_{COMPLEX}$ are measures of the water transport dynamics and floodplain structure that facilitate connectivity. The variable measure of large wood debris, V_{LWD}, reflects the ability to retain a major structural component of these floodplain systems. In the second part of the equation, V_{GEOMOD} is given geometric weighting in the model because of the strong interaction human disturbance (e.g., channel riprap, dikes, and levees) has on the continued function of the floodplain.

Function 4: Generation and Export of Organic Carbon

Definition. The Generation and Export of Organic Carbon is defined as the capacity of a riverine floodplain/wetland complex to generate organic carbon (both dissolved and particulate) through primary production and to export that carbon downstream to other riverine or floodplain habitats and systems. Mechanisms of export include leaching of litter, flushing, displacement, and erosion.

An independent quantitative measure of this function is the mass of carbon exported per unit area per unit time ($g/m^2/yr$) from the floodplain, into the river, and to the next river segment.

Rationale for Selecting the Function. Floodplains of alluvial gravel-bed rivers are zones of high bioproduction and diversity (Stanford and Ward 1993). The floodplain serves as a vital source of dissolved and particulate organic carbon for aquatic food webs and biogeochemical processes in downstream aquatic habitats (Vannote et al. 1980, Elwood et al. 1983, Cummins et al. 1989, Gregory et al. 1991, Tabbachi et al 1998). Dissolved organic carbon is a significant source of energy for the microbes that form the base of the detrital food web in aquatic ecosystems (Dahm 1981; Edwards 1987; Edwards and Meyers 1986, Benke et al. 1992). Evidence also suggests that the particulate fraction of organic carbon imported from uplands or produced in situ is an important energy source for shredders and filter-feeding organisms (Wallace et al. 1987, Cummins et al. 1989, Merritt and Cummins 1996).

Characteristics and Processes that Influence the Function. Floodplains and their associated wetlands of alluvial gravel-bed rivers can best be viewed as open ecosystems with significant flux of water and materials. A major

component of the material flux occurs within the organic fraction, both as dissolved carbon and as particulate organic matter (OM). Because of the high porosity of the alluvium distributed across the floodplain surface that has been worked and reworked by fluvial processes, the floodplain surface and subsurface is a complex mosaic of hydrologic affinities. Characteristic riparian vegetation is often highly productive, due to its vertical proximity to a water table maintained by the continuous supply of water from the river and the routing of water throughout the complex mosaic of surface and subsurface flow pathways. Thus, river-floodplains function as open systems structured by their hydrographic regimes and the fluvial geomorphology that facilitates the flow of materials.

Watersheds with large river floodplain-wetland complexes have generally been found to export organic carbon at higher rates than watersheds with fewer wetlands (Mulholland and Kuenzler 1979; Brinson, Lugo, and Brown 1981; Elder and Mattraw 1982; Johnston, Detenbeck, and Niemi 1990). This is attributable to several factors including: (1) the large amount of organic matter in the litter and soil layers that comes into contact with surface water during inundation by flooding, (2) relatively long periods of inundation and, consequently, contact between surface water and organic matter allowing for significant leaching of dissolved organic matter, (3) the ability of the labile carbon fraction to be rapidly leached from organic matter when exposed to water (Brinson, Lugo, and Brown 1981), and (4) the ability of floodwater to transport dissolved and particulate organic carbon from the floodplain to the stream channel.

This function is influenced onsite and offsite by: (1) the frequency of surface flooding of side channels, paleochannels, and other floodplain surfaces to transport organic matter from the floodplain back to the river ($V_{SURFREQ}$) and (2) the macrotopographic complexity (V_{MACRO}) of the floodplain. The function is also influenced by floodplain vegetation, in particular the density of trees in forested habitats (V_{DTREE}), the density of saplings and shrubs (V_{SHRUB}), and the density of herbaceous vegetation (V_{HERB}).

Description of Model Variables.

a. Frequency of Surface Flooding ($V_{SURFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull condition is surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of 10 years). However, the various habitats of a floodplain also exhibit different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 23). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleochannels flood at a frequency >10 years, then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never

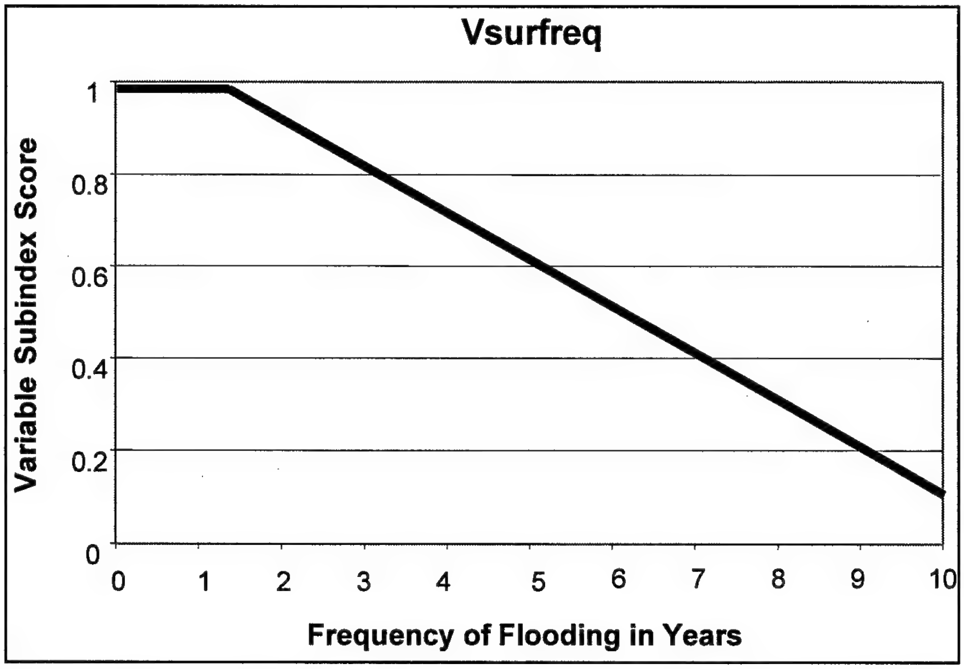


Figure 23. Function 4: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as a 0.0.

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8, based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

b. *Macrotopographic Complexity (V_{MACRO}).* This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools, and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, Macrotopographic (V_{MACRO}) Complexity is evaluated at the landscape spatial scale. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff

years, and thus is integral to the description and characterization of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature, it is critical to both onsite and offsite effects of modification to the floodplain.

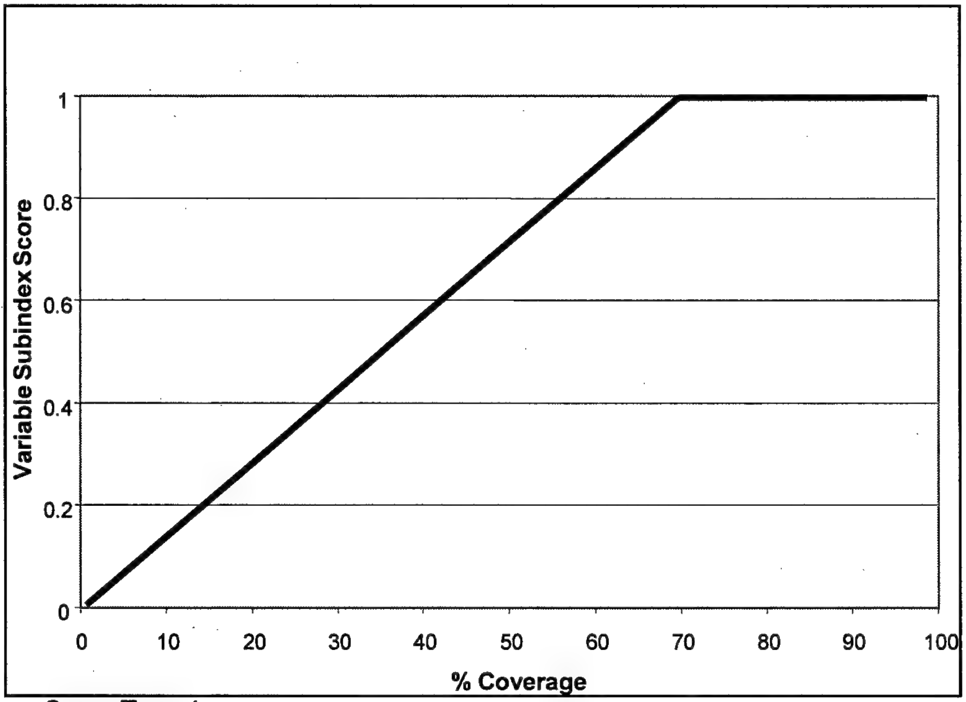
The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, it should be evaluated based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photos.

This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 14).

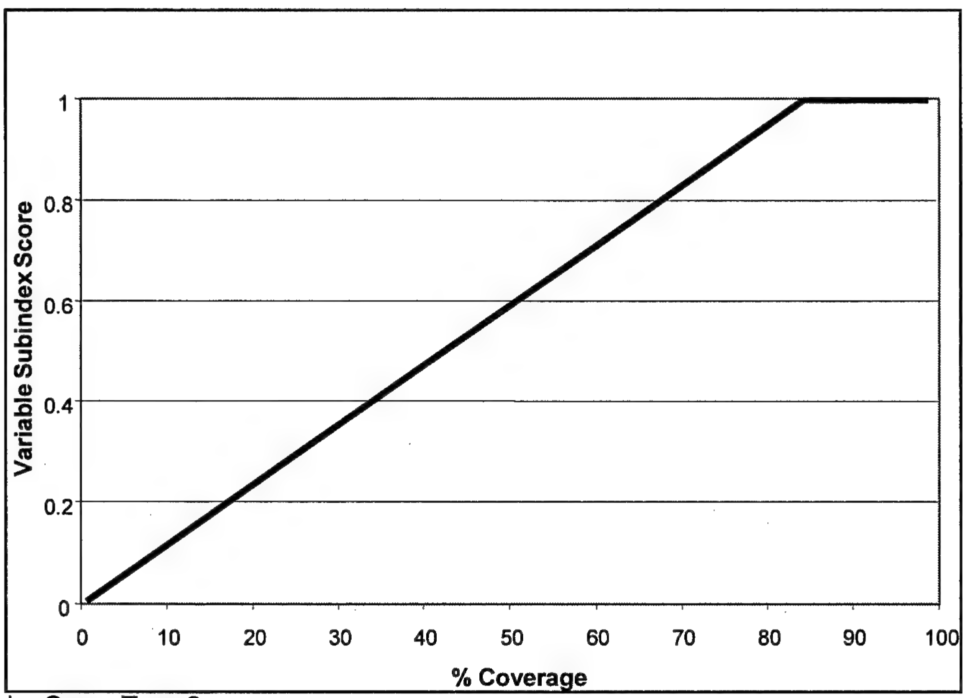
Table 14
Function 4: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

c. *Herbaceous Plant Coverage (V_{HERB}).* This variable represents the percent coverage of herbaceous plants per unit area across the floodplain by cover type. The herbaceous layer is defined as all herbaceous grasses and forbes that do not have woody stems. The herbaceous coverage changes between cover types and is one of the first variables to respond to human disturbance on the floodplain. Herbaceous coverage is measured as the percent coverage within a 1-m by 1-m plot. If the shrub coverage is being estimated within Cover Types 1-4 (tree- and shrub-dominated cover types) then the herbaceous coverage should be estimated within the larger plots. Figure 24 presents the density of herbs expressed as percent coverage and the corresponding Variable Subindex Scores for each of the six cover types that are evaluated for this variable.

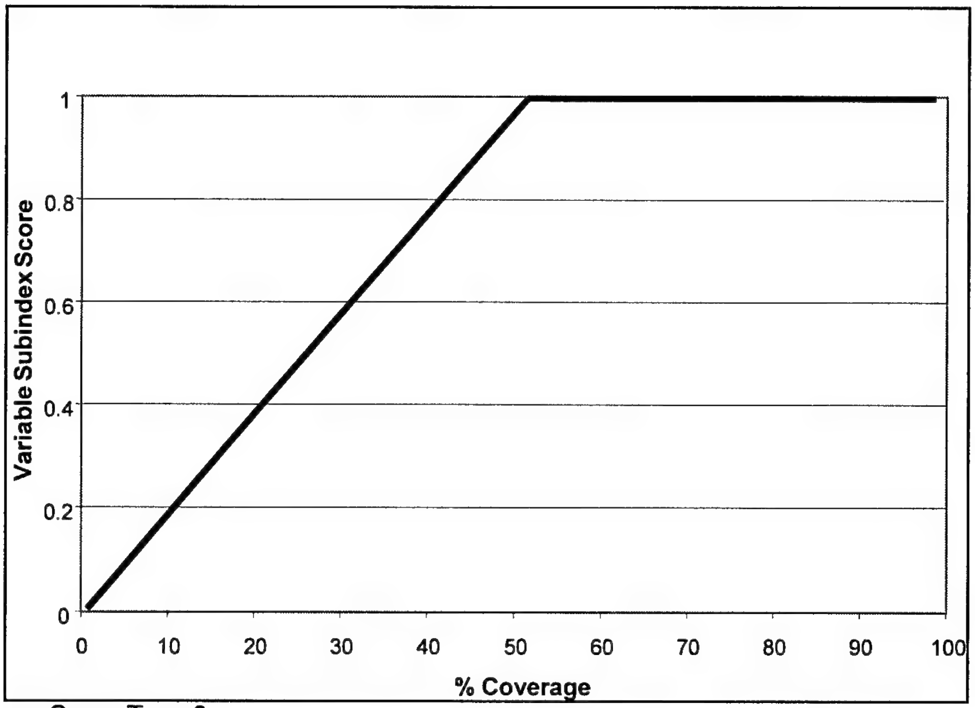


a. Cover Type 1

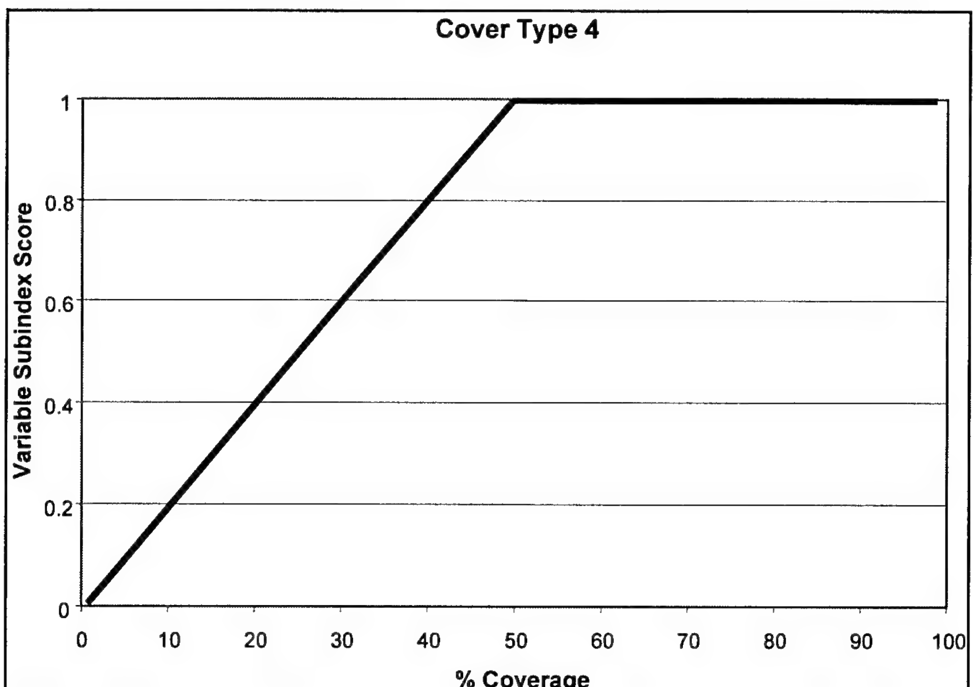


b. Cover Type 2

Figure 24. Function 4: Percent coverage of the herbaceous layer of plants and corresponding Variable Subindex Scores for Cover Types 1-6 (Sheet 1 of 3)

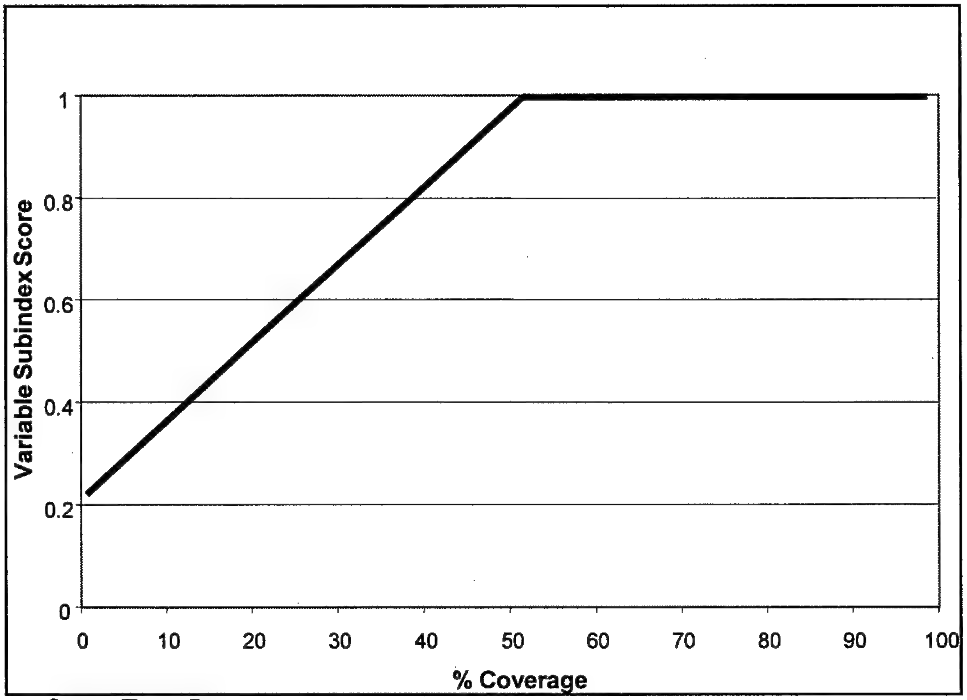


c. Cover Type 3

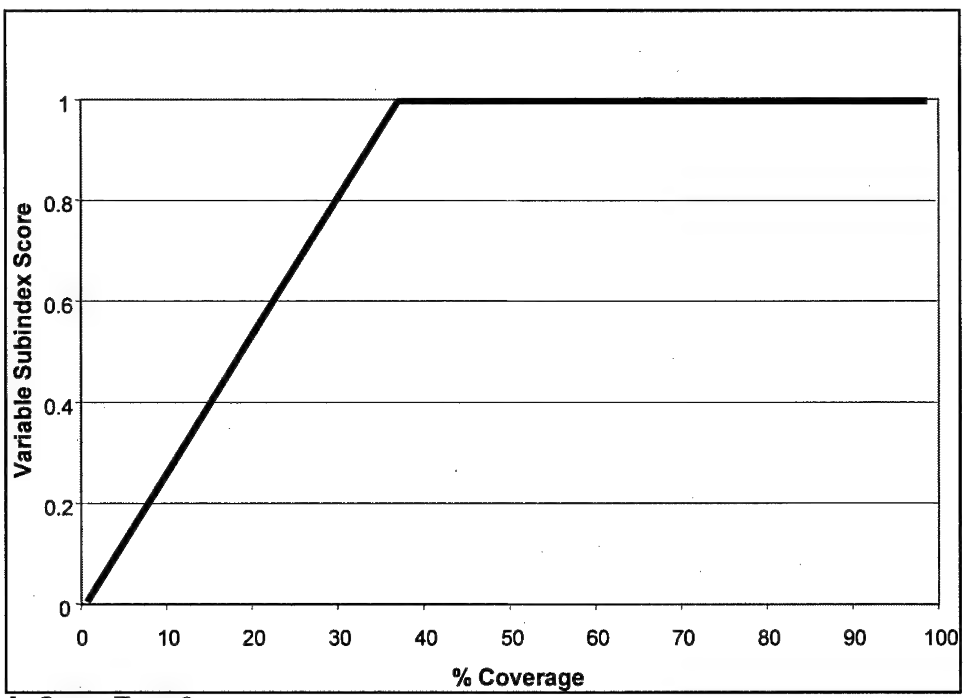


d. Cover Type 4

Figure 24. (Sheet 2 of 3)



e. Cover Type 5

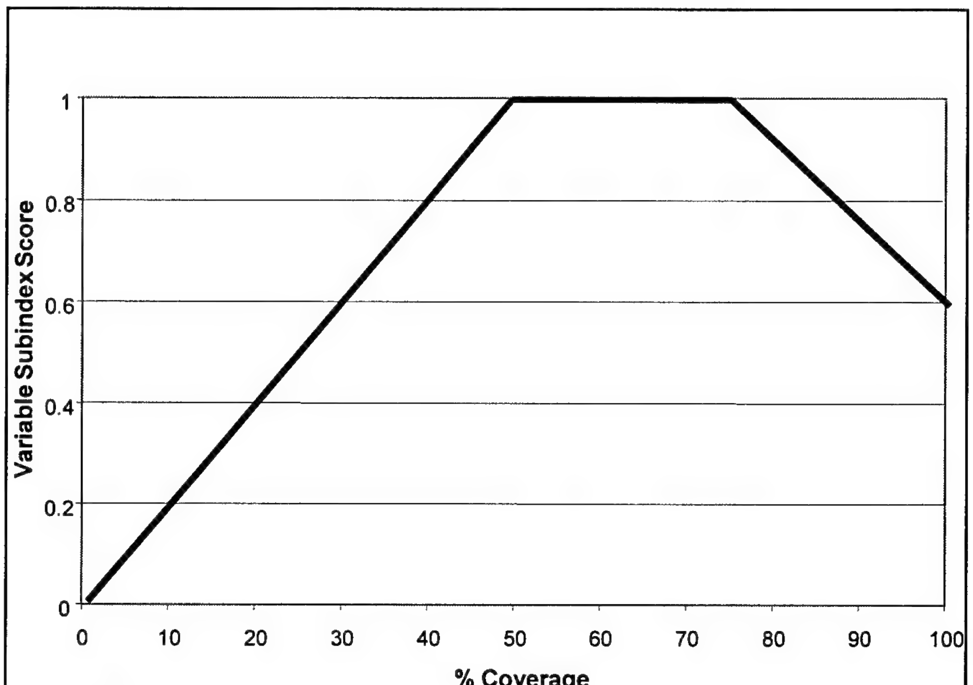


f. Cover Type 6

Figure 24. (Sheet 3 of 3)

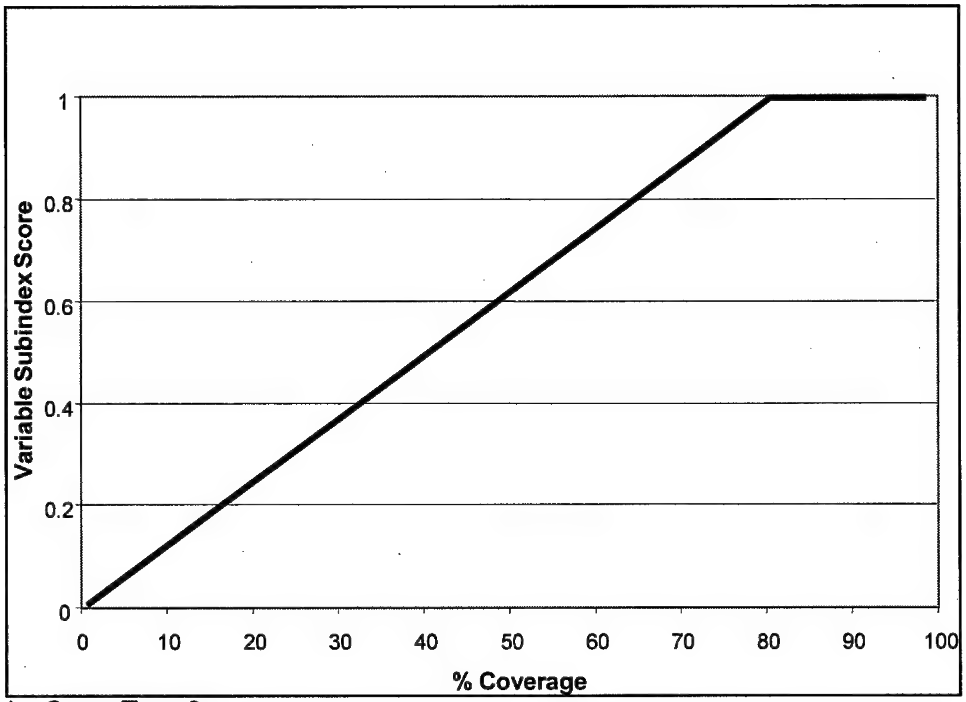
d. Pole Cottonwood, Willow, Shrub, and Sapling Coverage (V_{SHRUB}). This variable represents the percent coverage of shrubs and saplings per unit area across the forested and shrub-covered floodplain. Shrubs and saplings are defined as woody stems <6 m in height and <10 cm dbh. The shrub and sapling coverage changes between cover types. In the context of this variable, pole cottonwood, willow, and shrub density is measured as a function of percent coverage rather than stem density because of the high variability between species.

Shrub coverage is measured as the percent coverage within a 5- by 5-m plot. If the shrub coverage is being estimated within Cover Types 1-2 (tree-dominated cover types), then the plot should be taken as one of the quarter sections of the tree-density plots. Cover Type 3 and 4 plots are selected independently since the pole cottonwoods, saplings, and shrubs are the dominant woody species. It is common to encounter very narrow Cover Type 4 and 5 polygons as a result of fluvial processes on the floodplain and the subtle differences in elevation. When this occurs, plots should be extended in length and narrowed in width, yet a 25-m^2 plot should remain the standard plot size. Figure 25 presents the density of shrubs and saplings and the corresponding Variable Subindex Scores for each of the five cover types commonly having a major shrub component of the vegetation.

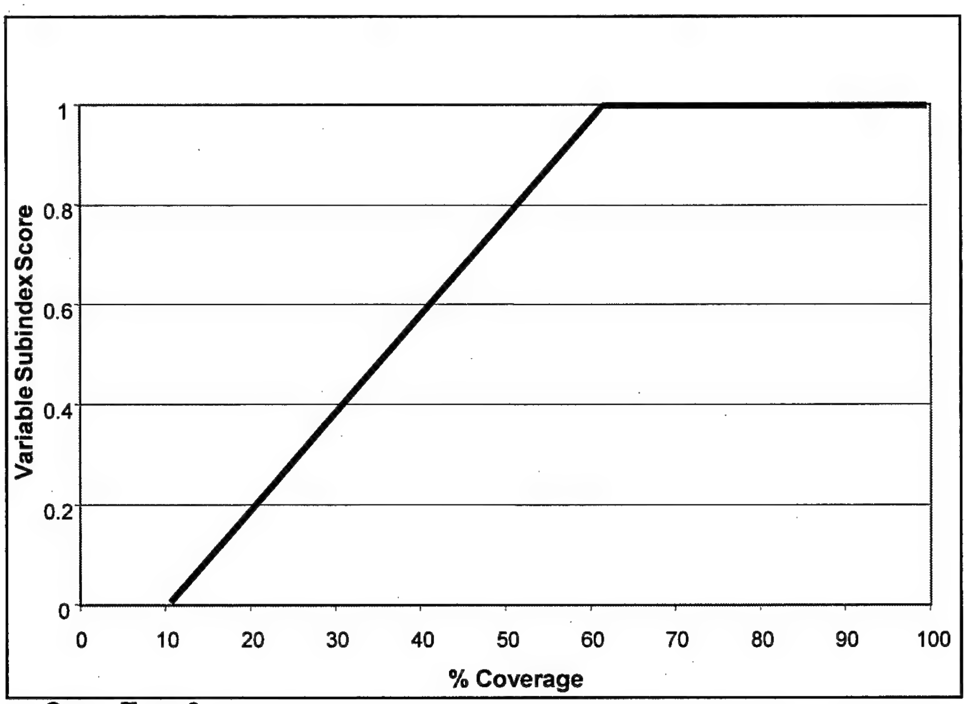


a. Cover Type 1

Figure 25. Function 4: Percent coverage of the shrub layer of plants and corresponding Variable Subindex Scores for Cover Types 1-5 (Sheet 1 of 3)

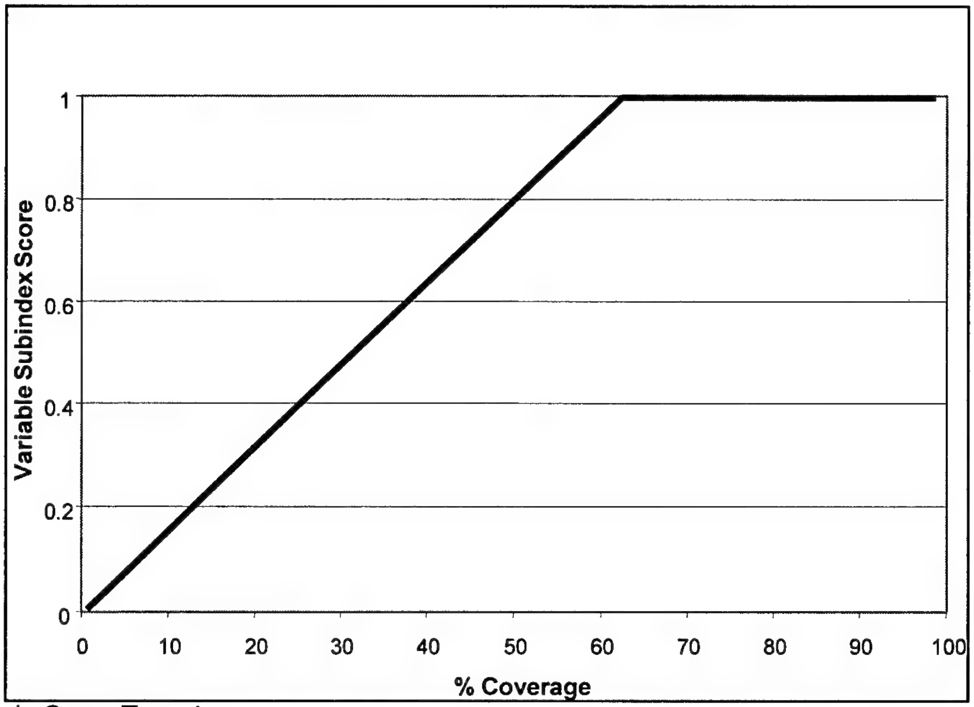


b. Cover Type 2

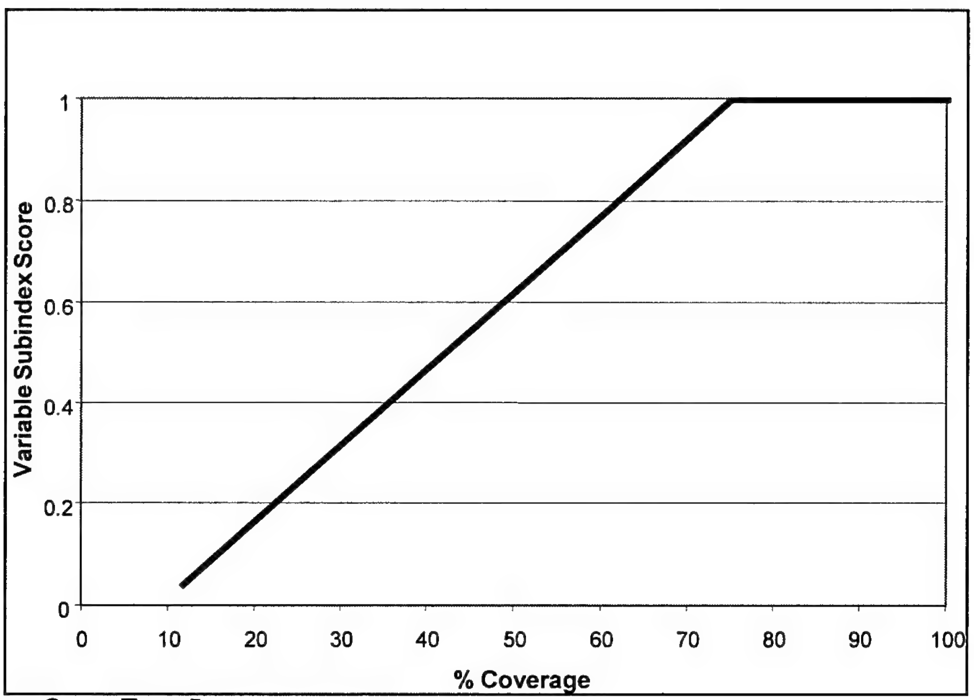


c. Cover Type 3

Figure 25. (Sheet 2 of 3)



d. Cover Type 4

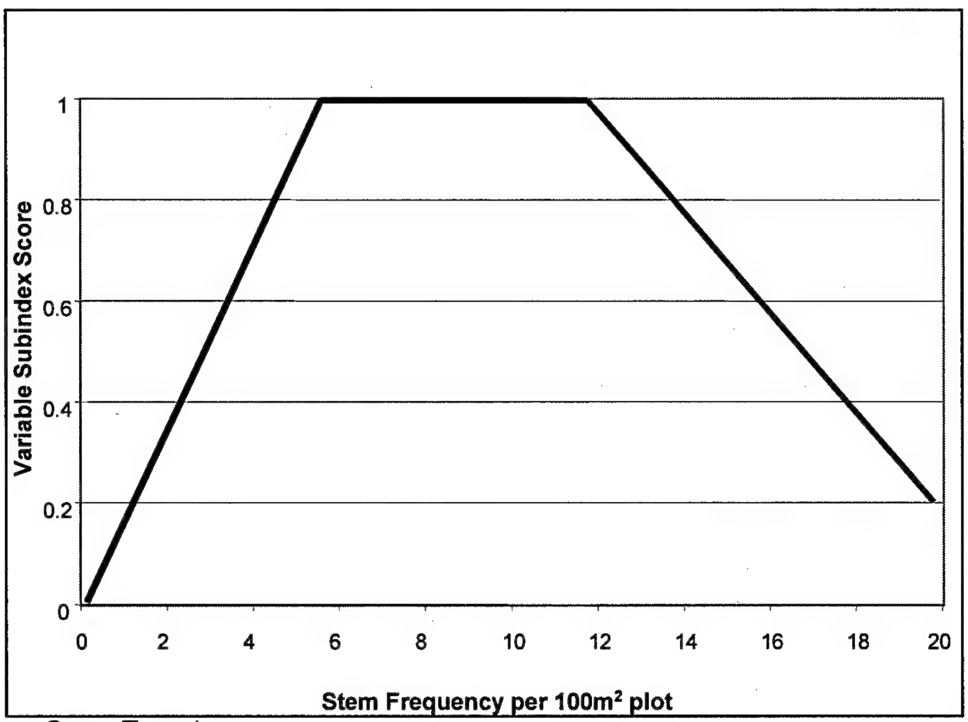


e. Cover Type 5

Figure 25. (Sheet 3 of 3)

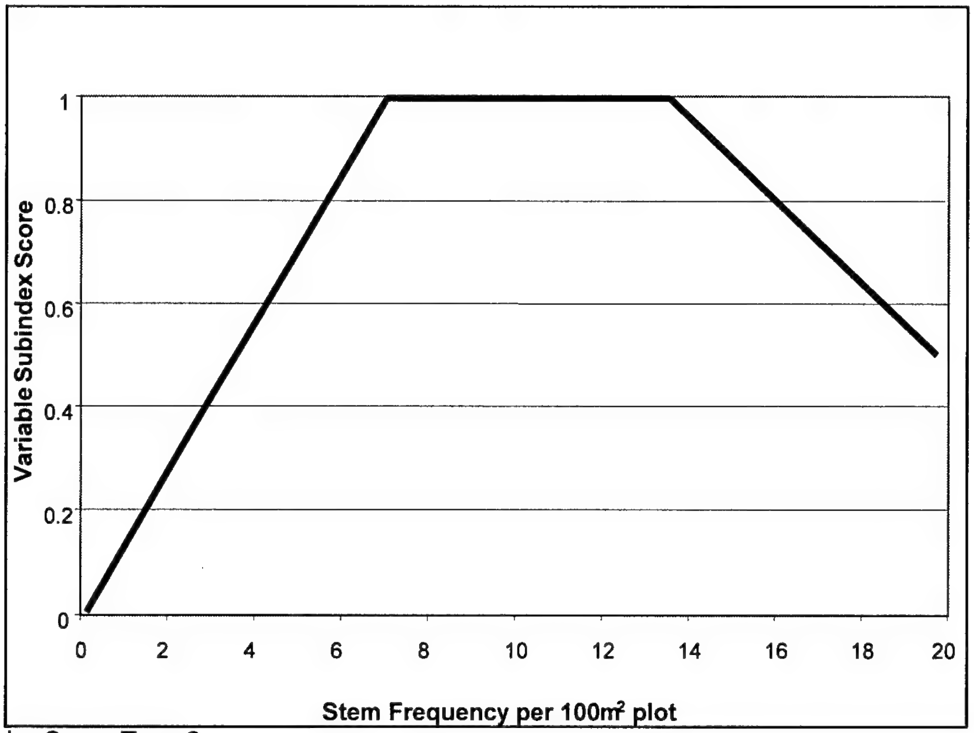
e. *Tree Density (V_{DTREE}).* This variable represents the number of trees per unit area across the forested cover types of the riparian floodplain wetlands. Trees are defined as woody stems ≥6 m in height or ≥10 cm dbh. In most forested systems, tree stem density and basal area increase rapidly during the early successional phases. This is also true in the northern Rocky Mountain floodplain systems. Thereafter, tree density decreases and basal area increases as the forest reaches mature steady-state conditions (Spurr and Barnes 1980). In the context of this function, tree density serves as an indicator of plant community structure.

Measure this variable by averaging the number of tree stems in a 10- by 10-m plot. If the density is low, increase the size of the plot, but relativize the data to number per 100-m^2. The number of sample plots required to adequately characterize the area being assessed will depend on its size and the heterogeneity of the forest within the cover type being evaluated; however, sample at least three plots in any one stand or floodplain polygon, more if heterogeneity is high. Average the results from all plots. The section on Assessment Protocols (Chapter 5) provides guidance for determining the number and layout of sample points and sampling units. Figure 26 presents the density of trees and the corresponding Variable Subindex Scores for the two cover types dominated by mature forest canopy trees.



a. Cover Type 1

Figure 26. Function 4: Tree stem density and corresponding Variable Subindex Scores for Cover Types 1 and 2 (Continued)



b. Cover Type 2

Figure 26. (Concluded)

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{MACRO}}{2} \right) \times \left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE}}{3} \right) \right]^{1/2}$$

In the model equation, retention of organic and inorganic particles depends on the following factors: (1) the frequency of surface flooding, (2) the macrotopographic relief of the floodplain, (3) the herbaceous plant communities, (4) the shrub layer of the plant communities, and (5) the tree layer of the plant communities. In the first part of the equation, $V_{SURFREQ}$ and V_{MACRO} are measures of the transport of waters and the macrotopographic features that provide surface flow pathways for material exchange. The equation expresses these two variables as an arithmetic mean. In the second part of the equation, V_{HERB}, V_{SHRUB}, and V_{DTREE} represent the sources of organic matter production on the floodplain and are calculated as an arithmetic mean. These two parts are placed within the context of the geometric mean.

Function 5: Characteristic Plant Community

Definition. Maintaining a Characteristic Plant Community is defined as the capacity of the floodplain-wetland complex to sustain a native plant community that is appropriate for the Reference Domain. Vegetation is maintained by

reference conditions, especially water regime, nutrient cycling, soil development, and disturbance regimes. Maintaining a plant community characteristic to the floodplains of the region also requires vegetative properties such as growth and development of propagules, seed dispersal, density, and growth rates that permit response to natural variation in climate and disturbance (e.g., floods, fire, herbivory). Major change in the relative proportions of vegetative cover and/or invasion by non-native plants and uncharacteristic native species is an indication that this function has been diminished.

Potential independent measures of this function include examination of the relative frequency of the various cover types of vegetation, relative density of the different vegetative layers, and direct measure of native plant coverage and densities.

Rationale for Selecting the Function. Floodplains of high gradient gravel-bed rivers form a complex mosaic of gravel and cobble substrata that are sorted and distributed through cut and fill alluviation (Stanford 1998). The interaction between the hydrograph, stream power, floodplain gradient, and size and supply of sediment directly affects floodplain geomorphology and the frequency of floodplain flooding and redistribution of materials that constitute ecosystem disturbance. Flooding and the distribution of power and sediment on the floodplain scours vegetated surfaces and deposits sediment that provides new surfaces for plant colonization (Tabbachi et al. 1998). A characteristic plant community develops across the floodplain surface in response to various physical (e.g., hydrologic, stream power, sediment, scour) and biological (e.g., colonization, competition) factors that greatly reflects a heterogeneous nature.

The ability of the floodplain to maintain a Characteristic Plant Community is important because of the intrinsic value of species diversity and the many attributes, functions, and processes floodplain vegetation perform. For example, primary productivity, nutrient cycling, and the ability to provide a variety of habitats necessary to maintain local and regional diversity of animals (Harris and Gosselink 1990) are directly influenced by the plant community. In addition, the plant community of a riverine wetland influences the quality of the physical habitat and biological diversity of adjacent rivers by modifying the quantity and quality of water (Elder 1985; Gosselink, Lee, and Muir 1990) and through the export of carbon (Bilby and Likens 1979; Hawkins, Murphy, and Anderson 1982).

A characteristic plant community is one that remains within a natural range of variation in production, coverage, and diversity and is primarily composed of native species. Clearly, a plant community that is dominated by non-native species does not qualify as being "characteristic" of an undisturbed state. Indeed, invasion by non-native plants is known to alter ecosystem processes causing both structural and functional change in the vegetative community (D'antonio and Vitousek 1992). Vitousek (1990) discusses ways that plant invasions can alter ecosystem processes, including whole-system fluxes and rates of resource supply. Examples of species invasions that have significantly changed ecosystem structure and function include *Tamarix* spp. in the southwestern United States and Australia (Griffin et al. 1989; Loope et al. 1988), ice-plants

(*Mesembryanthemum crystallinum* and *Carpobrotus edulis*) in California and Australia (Kloot 1983; Vivrette and Muller 1977; D'antonio 1990), and the nitrogen-fixer *Myrica faya*, which invades and dominates nitrogen-limited areas and increases inputs and availibility (Vitousek et al. 1987; Vitousek and Walker 1989). Likewise, invading species can alter the disturbance regime (e.g., type, frequency, intensity) of an ecosystem. For example a change in community characteristics can significantly alter fire frequency and intensity (MacDonald and Frame 1988; Smith and Tunison 1992; van Wilgen and Richardson 1985).

The goal of assessing this function is to evaluate plant species composition and community structure and to determine current conditions and community successional patterns and status. There are inherent problems associated with properly assessing this function, even though there is a rich literature base that has been directed toward plant community dynamics. These problems are twofold. First, vegetation is dynamic, responding to natural variation and anthropogenic influence; secondly, many wetland species are strongly influenced by periodic disturbances, such as fire, that reset successional patterns. In recognition that vegetation is dynamic, but often operating on long-term responses to changing environmental conditions, one should take the approach of combining direct measures of vegetation characteristics and measures of environmental factors. Thus, to develop the appropriate Index of Function, one must consider land-use practices and water regimes in addition to vegetative characterization.

Characteristics and Processes that Influence the Function. A characteristic plant community is maintained by a variety of biophysical variables. Several gradients influence the distribution and abundance of plant species. Not surprisingly, numerous studies have found that depth of water strongly influences vegetation patterns (Mitsch and Gosselink 1993). Likewise, the chemistry of water has a marked effect on nutrient availability and thus on plant species composition. Vegetation growing on the floodplain accounts for the vast majority of the organic matter supply to the floodplain-wetland complex that supports higher trophic levels. The higher trophic levels, in turn, influence the structure of the vegetative community through herbivory and decomposition of detrital biomass. Thus, vegetation is also the primary source of organic matter that fuels the detrital-microbial decomposition process.

Vegetation is significantly affected by other wetland ecosystem functions associated with hydrology (e.g., evapotranspiration, surface roughness) and nutrient cycling (e.g., nitrogen, phosphorus). Thus, vegetation is an interactive component of the river-floodplain-wetland ecosystem structure and function, operating both as a response variable to driving mechanisms (e.g., hydrologic regime, geomorphology) as well as being a driving mechanism for other floodplain functions (e.g., nesting habitat, primary productivity). Vegetation should not be considered as static, but rather as changing in composition and characteristics over a hierarchy of temporal scales; annual cycles, multi-year life history cycles, and as floodplain surfaces are affected by cut ad fill alluviation.

This function is influenced onsite and offsite by the density of trees in forested habitats (V_{DTREE}), the density of saplings and shrubs (V_{SHRUB}), and the

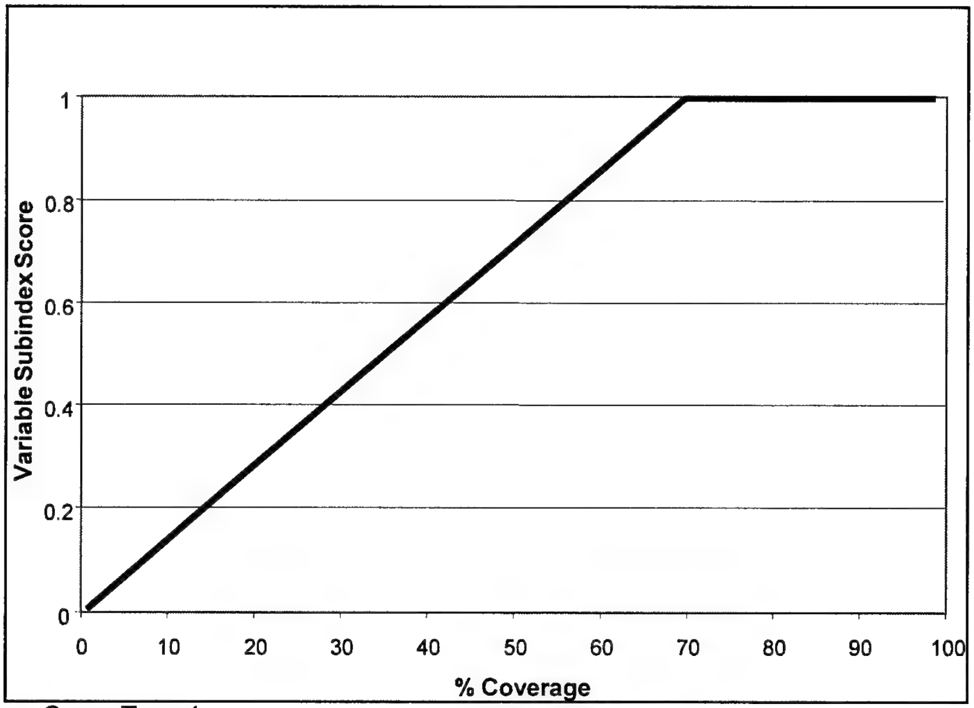
density of herbaceous vegetation (V_{HERB}). The function is also related directly to the weighted mean percent coverage of native plants (V_{NPCOV}) within each of the floodplain surface cover types. Rates of processes (e.g., elemental cycling, detritus accumulation) as well as animal populations are adapted to native plants for food, cover, nesting, etc. Non-native plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance. Finally, this function occurs in a reference standard condition within the context of a specific floodplain complexity of vegetation types ($V_{COMPLEX}$).

Description of Model Variables.

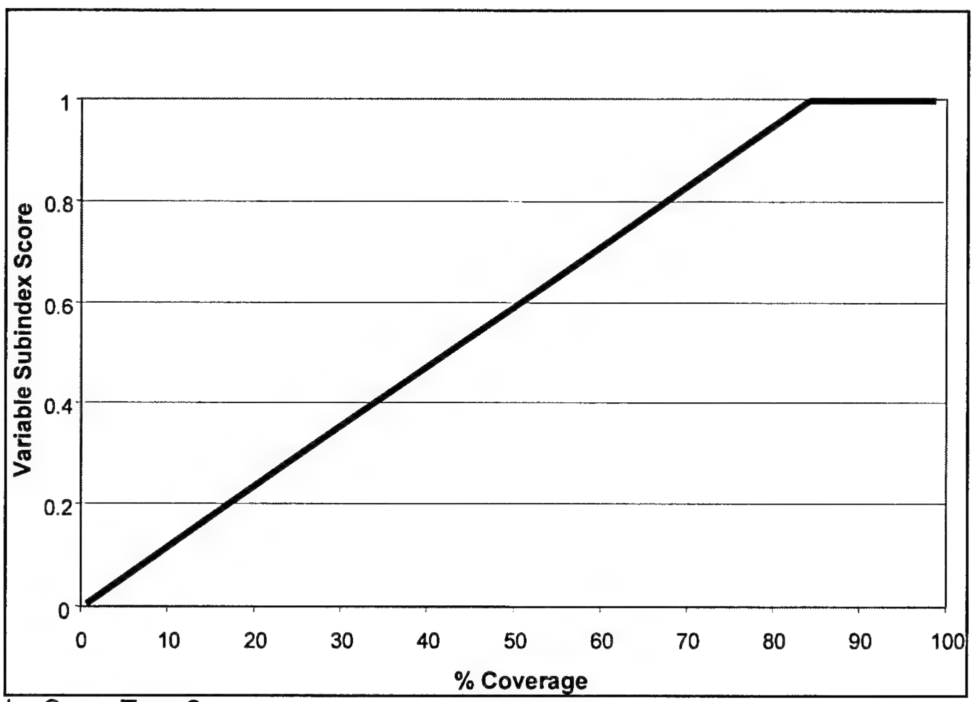
a. *Herbaceous Plant Coverage (V_{HERB}).* This variable represents the percent coverage of herbaceous plants per unit area across the floodplain by cover type. The herbaceous layer is defined as all herbaceous grasses and forbes that do not have woody stems. The herbaceous coverage changes between cover types and is one of the first variables to respond to human disturbance on the floodplain. Herbaceous coverage is measured as the percent coverage within a 1-m by 1-m plot. If the shrub coverage is being estimated within Cover Types 14 (tree- and shrub-dominated cover types), then the herbaceous coverage should be estimated within the larger plots. Figure 27 presents the density of herbs expressed as percent coverage and the corresponding Variable Subindex Scores for each of the six cover types that are evaluated for this variable.

b. *Pole Cottonwood, Willow, Shrub, and Sapling Coverage (V_{SHRUB}).* This variable represents the percent coverage of shrubs and saplings per unit area across the forested and shrub covered floodplain. Shrubs and saplings are defined as woody stems <6 m in height and <10 cm dbh. The shrub and sapling coverage changes between cover types. In the context of this variable, pole cottonwood, willow, and shrub density is measured as a function of percent coverage rather than stem density because of the high variability between species.

   Shrub coverage is measured as the percent coverage within a 5- by 5-m plot. If the shrub coverage is being estimated within Cover Types 1-2 (tree-dominated cover types) then the plot should be taken as one of the quarter sections of the tree density plots. Cover Type 3 and 4 plots are selected independently since the pole cottonwoods, saplings, and shrubs are the dominant woody species. It is common to encounter very narrow Cover Type 4 and 5 polygons as a result of fluvial processes on the floodplain and the subtle differences in elevation. When this occurs, plots should be extended in length and narrowed in width, yet a 25-m^2 plot should remain the standard plot size. Figure 28 presents the density of shrubs and saplings and the corresponding Variable Subindex Scores for each of the five cover types commonly having a major shrub component of the vegetation.

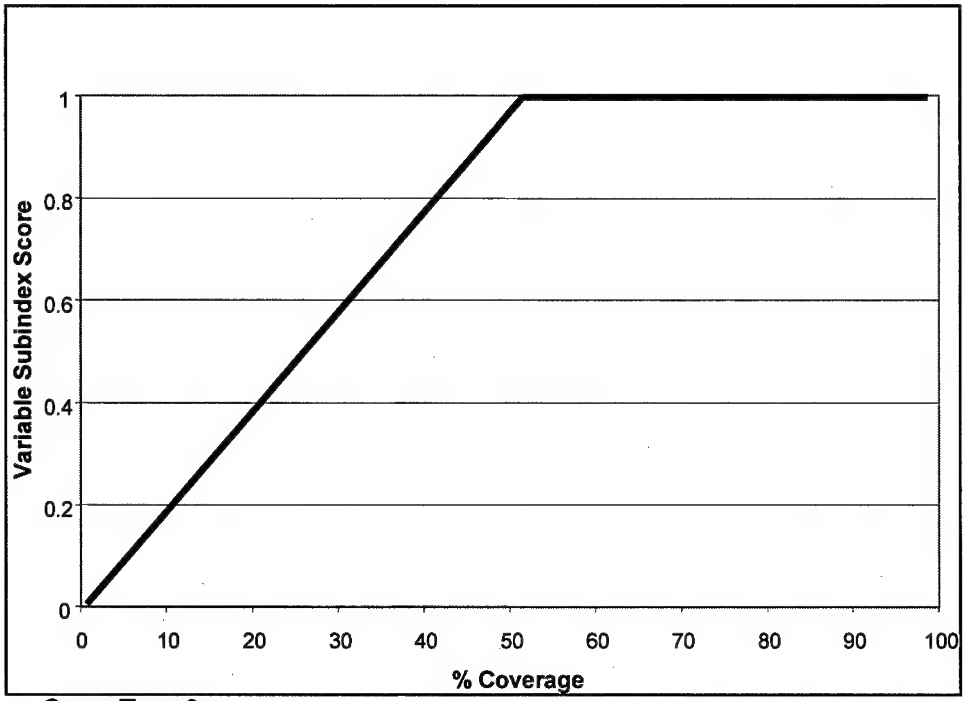


a. Cover Type 1

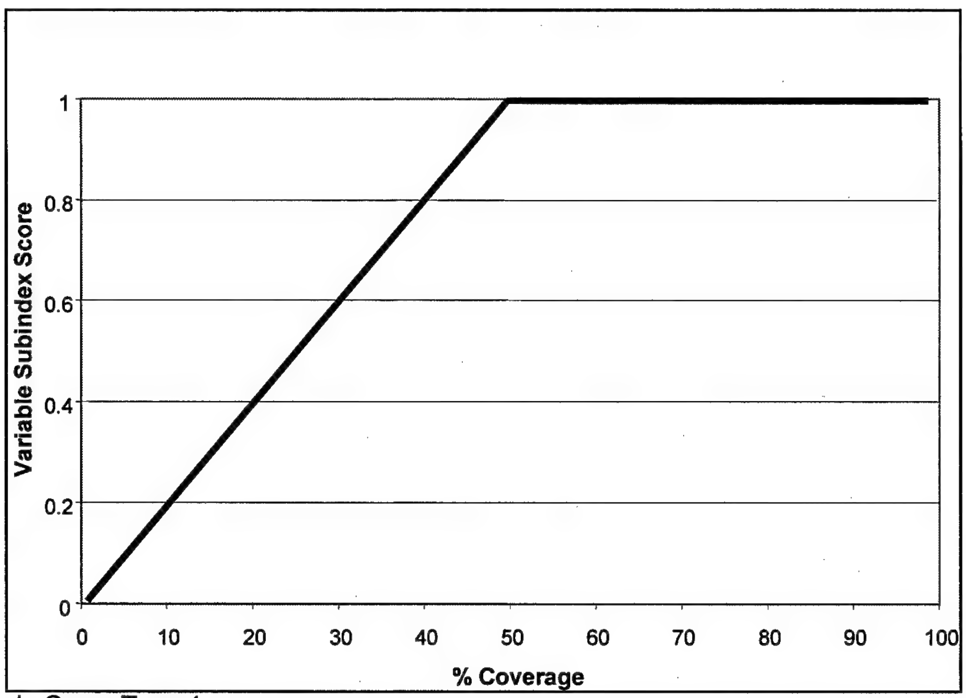


b. Cover Type 2

Figure 27. Function 5: Percent coverage of the herbaceous layer of plants and corresponding Variable Subindex Scores for Cover Types 1-6 (Sheet 1 of 3)

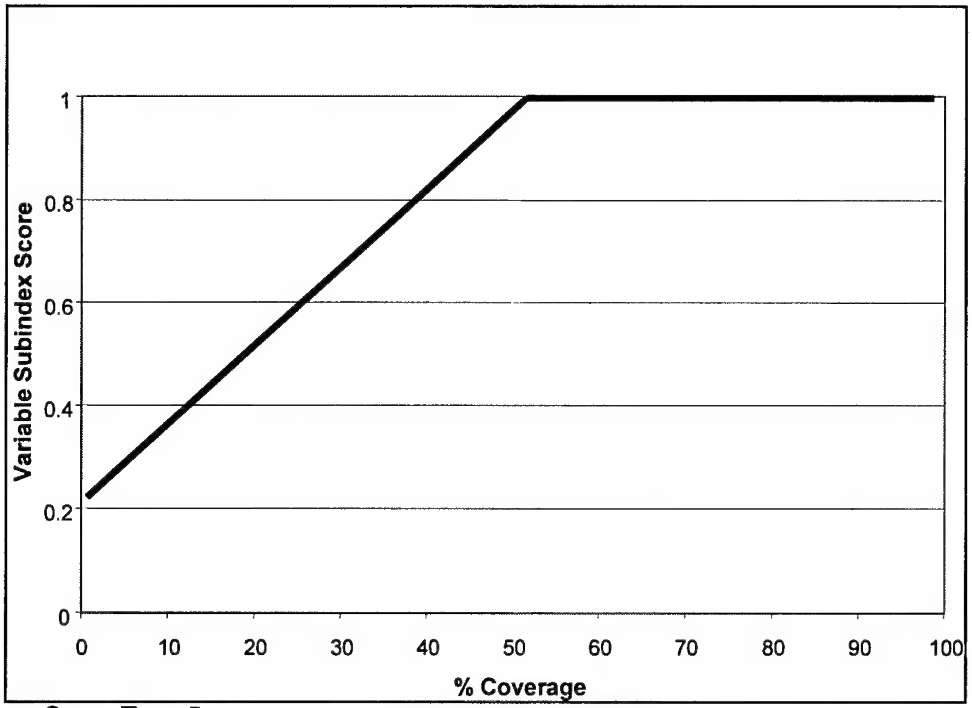


c. Cover Type 3

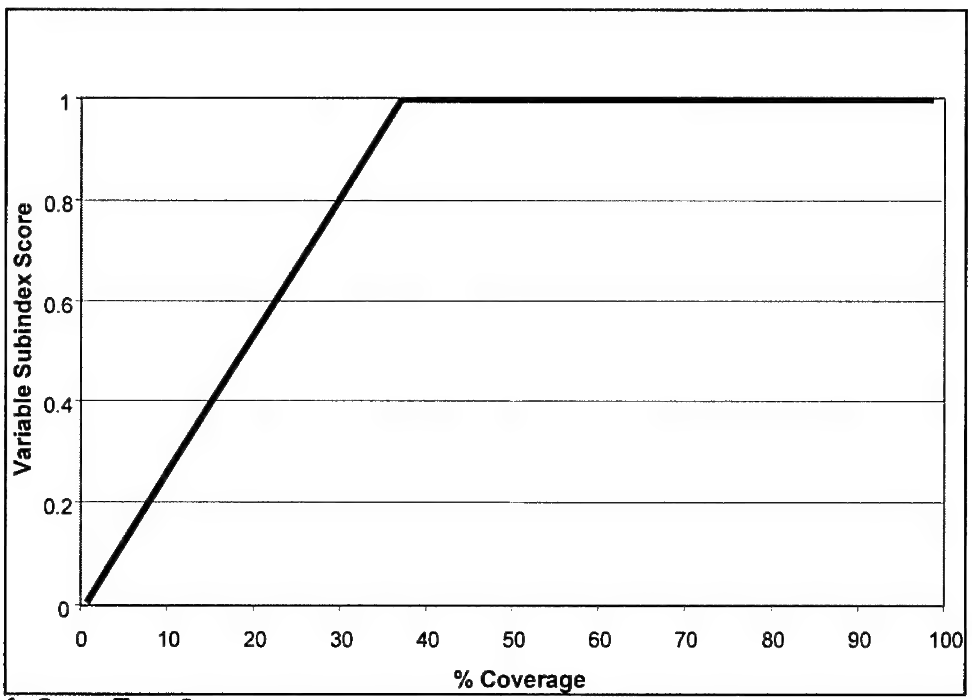


d. Cover Type 4

Figure 27. (Sheet 2 of 3)

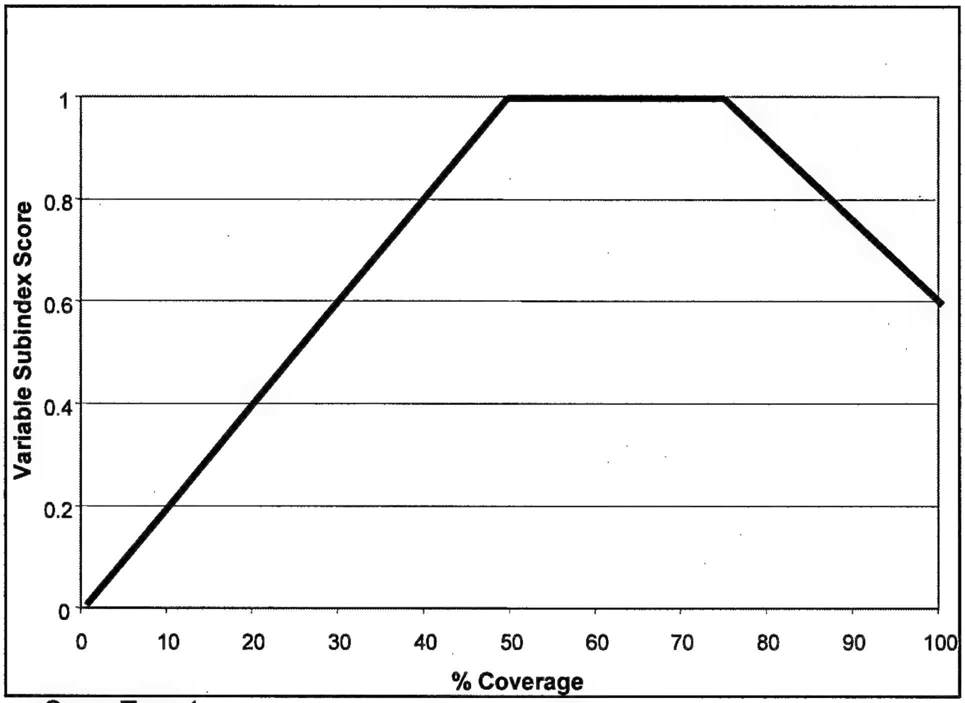


e. Cover Type 5

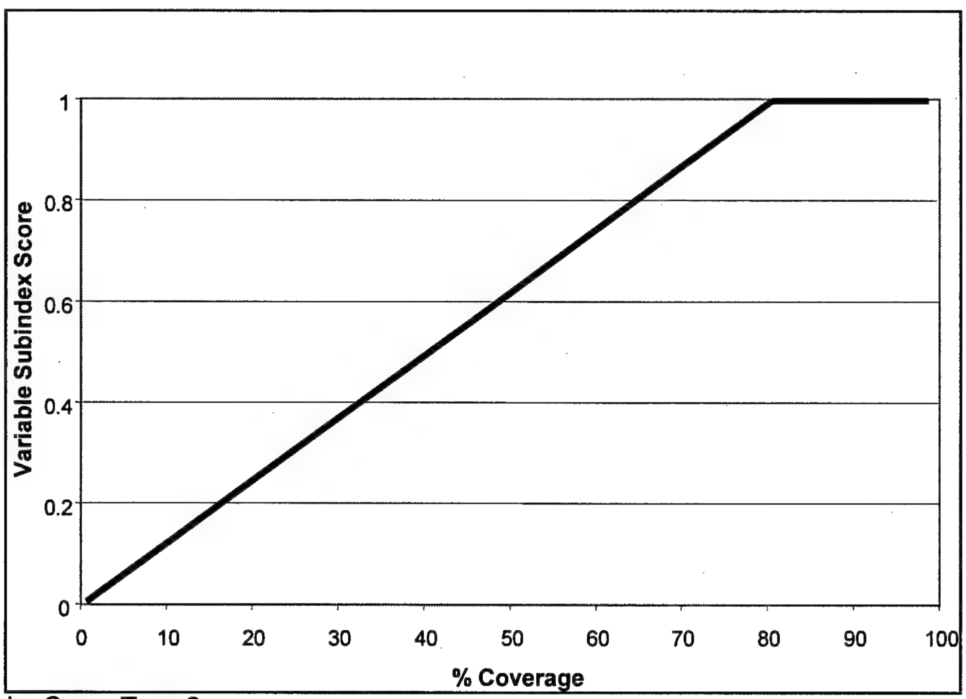


f. Cover Type 6

Figure 27. (Sheet 3 of 3)

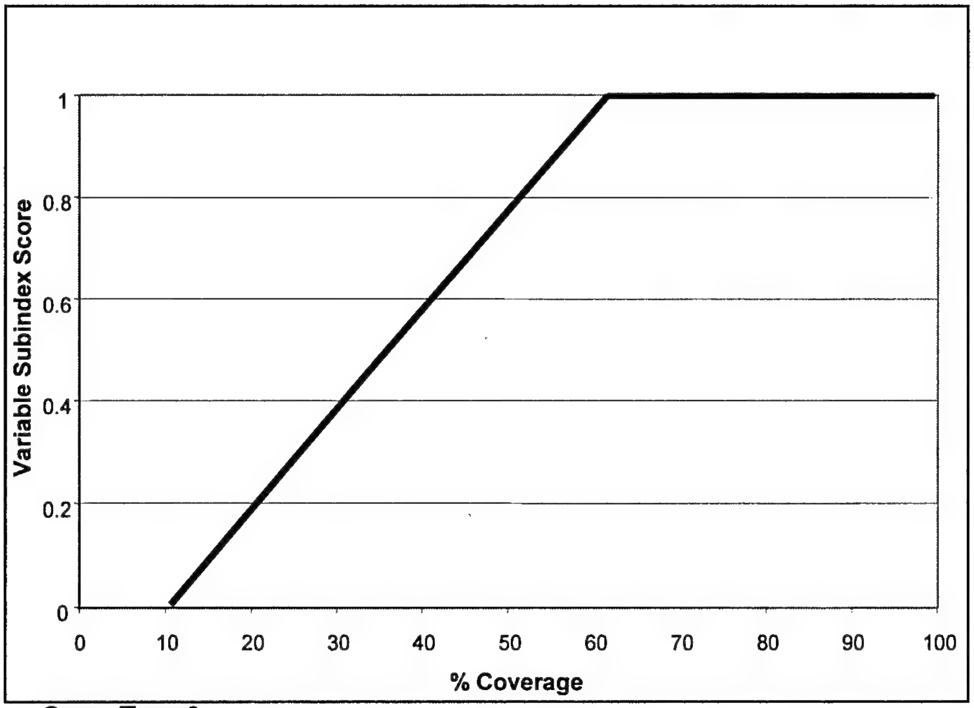


a. Cover Type 1

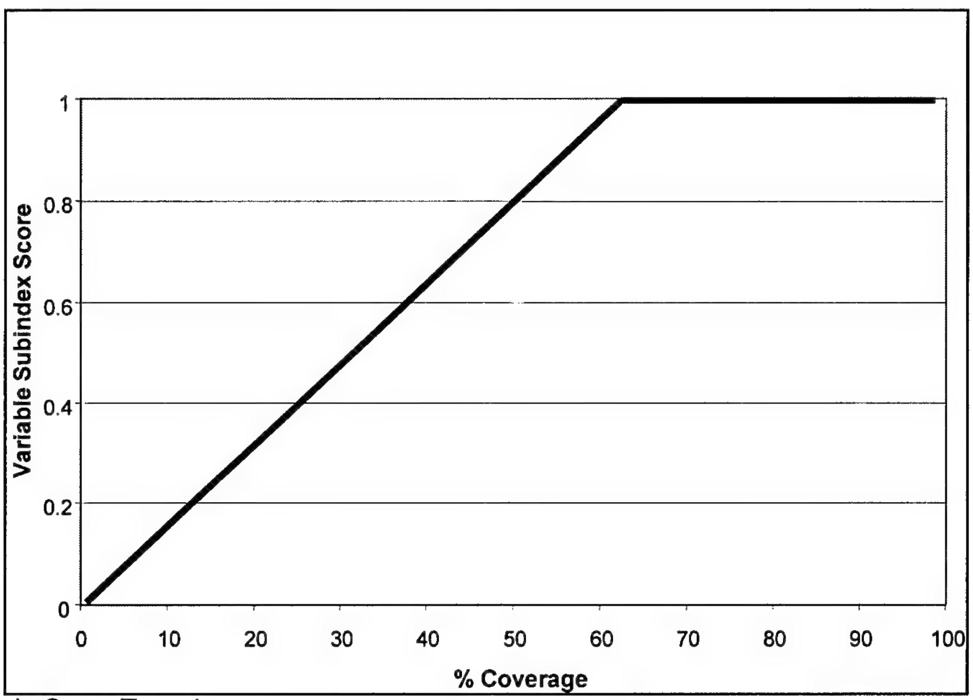


b. Cover Type 2

Figure 28. Function 5: Percent coverage of the shrub layer of plants and corresponding Variable Subindex Scores for Cover Types 1-5 (Sheet 1 of 3)

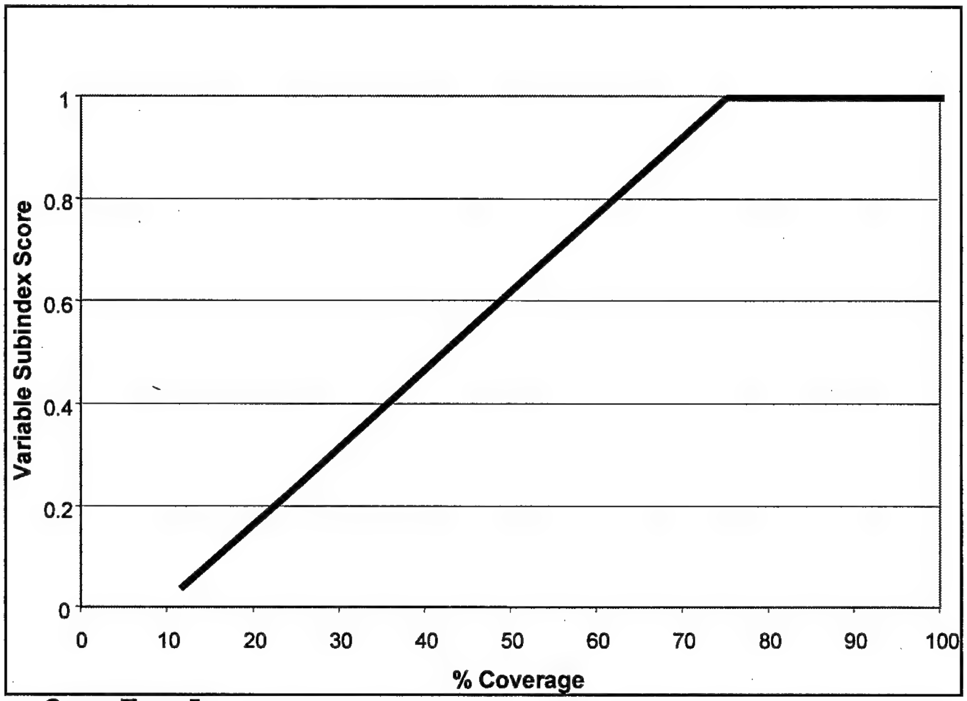


c. Cover Type 3



d. Cover Type 4

Figure 28. (Sheet 2 of 3)

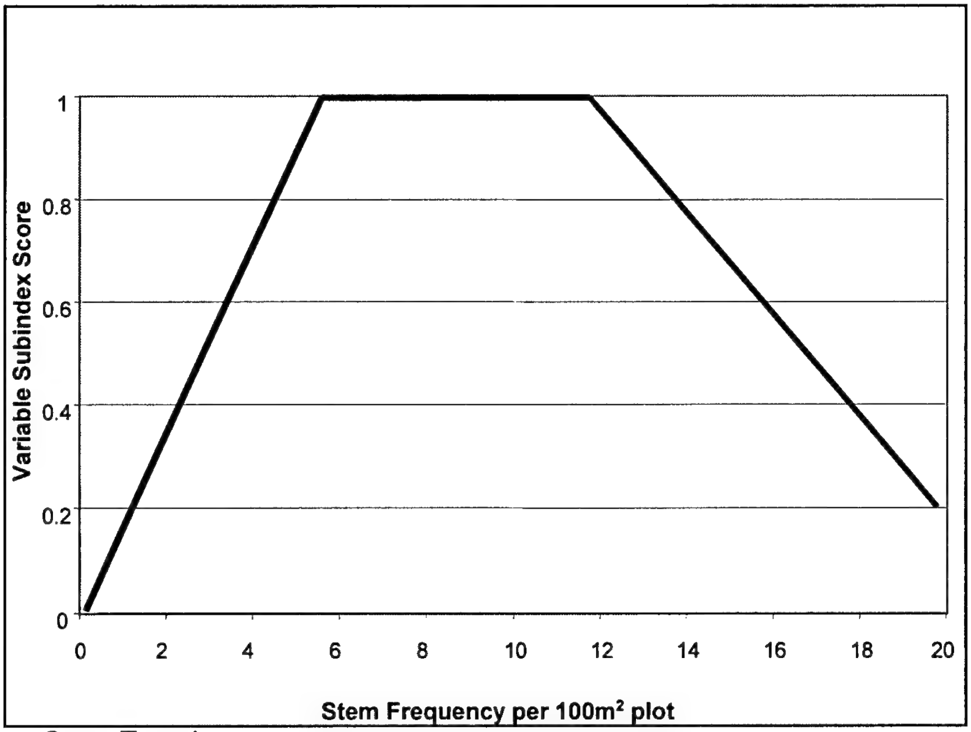


e. Cover Type 5

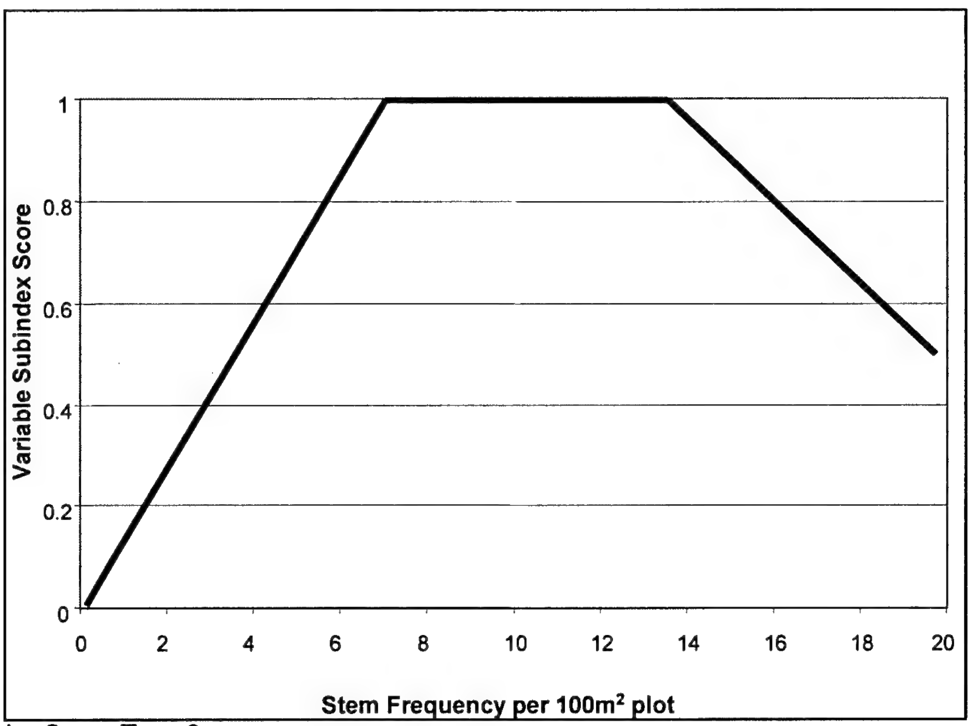
Figure 28. (Sheet 3 of 3)

c. *Tree Density (V_{DTREE}).* This variable represents the number of trees per unit area across the forested cover types of the riparian floodplain wetlands. Trees are defined as woody stems ≥6 m in height or ≥10 cm dbh. In most forested systems, tree stem density and basal area increase rapidly during the early successional phases. This is also true in the northern Rocky Mountain floodplain systems. Thereafter, tree density decreases and basal area increases as the forest reaches mature steady-state conditions (Spurr and Barnes 1980). In the context of this function, tree density serves as an indicator of plant community structure.

This variable may be measured by averaging the number of tree stems in a 10- by 10-m plot. If the density is low, increase the size of the plot, but relativize the data to number per 100 m^2. The number of sample plots required to adequately characterize the area being assessed will depend on its size and heterogeneity of the forest within the cover type being evaluated; however, at least three plots in any one stand or floodplain polygon should be sampled, more if heterogeneity is high. The results from all plots are then averaged. Chapter 5 (Assessment Protocols) provides guidance for determining the number and layout of sample points and sampling units. Figure 29 presents the density of trees and the corresponding Variable Subindex Scores for the two cover types dominated by mature forest canopy trees.



a. Cover Type 1



b. Cover Type 2

Figure 29. Function 5: Tree stem density and corresponding Variable Subindex Scores for Cover Types 1 and 2

d. *Proportionality of Landscape Features* ($V_{COMPLEX}$). This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. See the descriptions given in Chapter 5 (Assessment Protocols) for determining the appropriate size or area of floodplain to be assessed.

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 15 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/ floodplain complex can be described by a combination of conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and that often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and cover 15-25 percent of the surface area. Likewise, the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

Table 15
Function 5: Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect the Reference Standard Condition as a Condition that has been Significantly Impacted with Loss of Floodplain Complexity

	Variable Subindex Score								
Cover Type	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

e. *Percent Coverage by Native Plants (V_{NPCOV}).* Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) as well as animal populations are adapted to native plants for food, cover, nesting, etc. Non-native plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance. For example, tamarisk (salt cedar) is a major invader of river floodplains in the interior west, particularly where dams or diversions have altered the hydrographic regime. Likewise, spotted knapweed is an invader of disturbed areas that significantly competes with the native plant community.

This variable represents the weighted mean percent coverage of native plants within each vegetation cover type on the floodplain. The concept and calculation of this variable is a measure of the percent coverage by all native plants. This variable is calculated by estimating the Variable Subindex Score for each vegetation layer and each cover type (Figure 30) and weighting that score by the percent of each cover type within the Assessment Area.

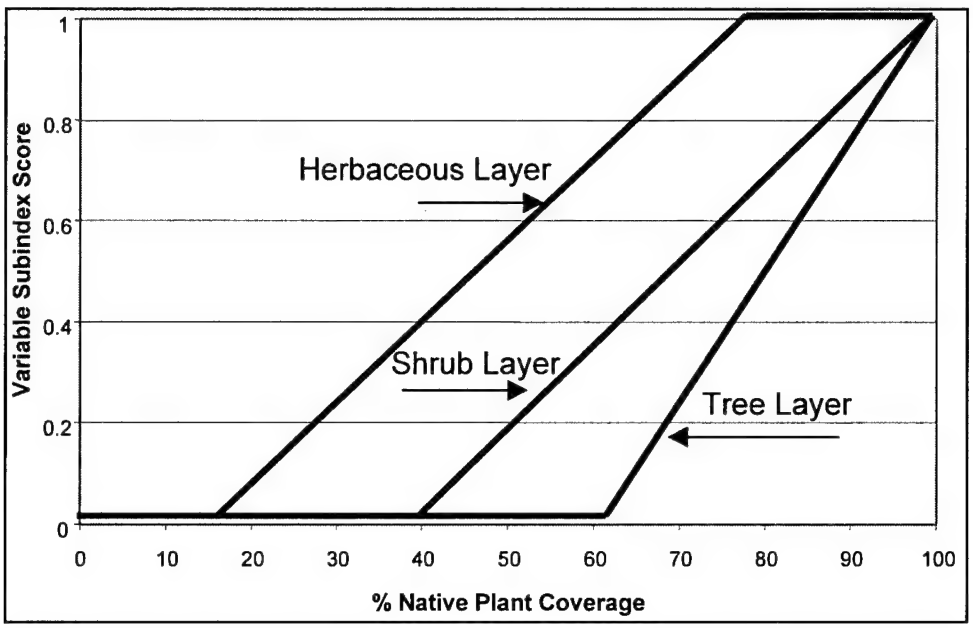


Figure 30. Function 5: Correlation between percent Native Plant Cover and corresponding Variable Subindex Scores by vegetation layer

Functional Capacity Index. The assessment model for calculating the Functional Capacity Index (FCI) is as follows:

$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE} + V_{COMPLEX}}{4}\right) \times V_{NPCOV}\right]^{1/2}$$

In the model equation, maintain characteristic plant communities, the function depends on the following factors: (1) the herbaceous plant communities, (2) the shrub layer of the plant communities, (3) the tree layer of the plant communities, (4) the relative complexity of these vegetation coverages occurring in the appropriate proportions and (5) the proportion of native plants within each of the various vegetation coverages. In the first part of the equation, V_{HERB}, V_{SHRUB}, V_{DTREE}, and $V_{COMPLEX}$ are measures of the density of vegetation within communities and the relative proportionality of those communities as a complex on the floodplain surface. The equation expresses these four variables as an arithmetic mean. The second part of the equation represents the proportionality of native plants V_{NPCOV} weighted by vegetative cover type across the Assessment Area. These two separate parts are placed within the context of the geometric mean because, in particular, if native plant coverage is at zero, this function does not occur because it is no longer "characteristic."

Function 6: Characteristic Aquatic Invertebrate Food Webs

Definition. The function Maintain Characteristic Aquatic Invertebrate Food Webs is defined as the capacity of the river floodplain to maintain a characteristic diversity and abundance of aquatic invertebrates. Invertebrates are subject to considerable variation over the annual climatic cycle, thus leading to inaccuracies in functional assessments if the assessment period occurs at a time of the year when densities or diversity are naturally low. Invertebrates may also be difficult to collect, identify, and enumerate without extensive training. Therefore, within the framework of a Hydrogeomorphic Functional Assessment of northern Rocky Mountain alluvial floodplains, this function is based on the evaluation of habitat, vegetation structure, hydrographic regime, and the complexity of the floodplain mosaic rather than direct measures of the invertebrates.

An independent measure of this function would include use of the Index of Biological Integrity (Karr and Chu 1997) or other approach to using macroinvertebrates as indicators of impact (Resh, Meyers, Hannaford 1996). This may include extensive sampling and multivariate analyses (Reynoldson et al. 1997) to assess and ascribe the degree of departure from a characteristic condition, particularly as intensity and breadth of impact increases.

Rationale for Selecting the Function. The aquatic habitats of alluvial river floodplains (e.g., fluvial depression wetlands, springbrooks) are important sources of aquatic invertebrates that: (1) process organic matter and are often major contributors to decomposition, (2) play an essential role in nutrient cycling, and (3) provide important conduits of trophic support for higher level consumers through the secondary production of their populations. Aquatic insects are particularly sensitive to diminished water quality, thus healthy populations are indicative of physiochemical conditions that are normative (e.g., nontoxic, appropriate thermal regimes, sufficient duration of flooding). The structure of invertebrate assemblages is sensitive to, and determined by, the conditions and resources available within a habitat. In the analysis of this function, the focus is on the ability of the floodplain ecosystem to support and maintain a balanced, adaptive community of invertebrate organisms. This is

accomplished through an analysis of critical habitat as well as diversity of habitat structure across the river floodplain mosaic.

Characteristics and Processes that Influence the Function. An extraordinary body of research has been directed toward understanding aquatic invertebrate populations and their dynamics in stream and river systems (sensu Hynes 1970, Merritt and Cummins 1996). However, much less is specifically known about the distribution and abundance of aquatic invertebrates across the plethora of complex aquatic habitats that characterize the riverine floodplains of the reference domain.

Aquatic invertebrates, particularly insects, crustaceans, and mollusks, are often diverse and abundant in floodplain springbrook and marsh habitats. Hundreds of species commonly occupy a variety of benthic, epiphytic, lentic, and lotic habitats (Merritt and Cummins 1996). Although macroinvertebrates have many characteristics that make them ideal for freshwater biomonitoring programs (Rosenburg and Resh 1993) the ecology of floodplain macroinvertebrates is not as well understood. Yet, we do know that macroinvertebrates may serve as sentinel organisms for early warning of water pollution or losses of continuity of particular habitats (Resh et al. 1996). Likewise, the presence of particular habitats results in a characteristic fauna. Macroinvertebrates have been shown to be sensitive to a variety of environmental changes and contaminants. Many species react strongly to toxic metals and organic pollution, acidification, salinization, sedimentation, and habitat fragmentation and disturbance (Anderson 1982; Pontasch, Smith, and Cairns 1989; Camargo, Ward, and Martin 1992).

Aquatic invertebrates are particularly influenced by changes in water regimes $V_{SURFREQ}$ and $V_{SUBFREQ}$. Factors that directly affect the quantity or temporal periodicity of water flow and connectivity to floodplain habitats (V_{MACRO}) will have a significant effect on the life histories, distribution, and abundance of aquatic invertebrates. These food webs are dependent on a characteristic frequency of various floodplain habitats ($V_{COMPLEX}$).

Description of Model Variables.

a. Frequency of Surface Flooding ($V_{SURFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull condition is having surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of 10 years). However, the various habitats of a floodplain also exhibit different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel and into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 31). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleo-channels flood at a frequency >10 years, then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never

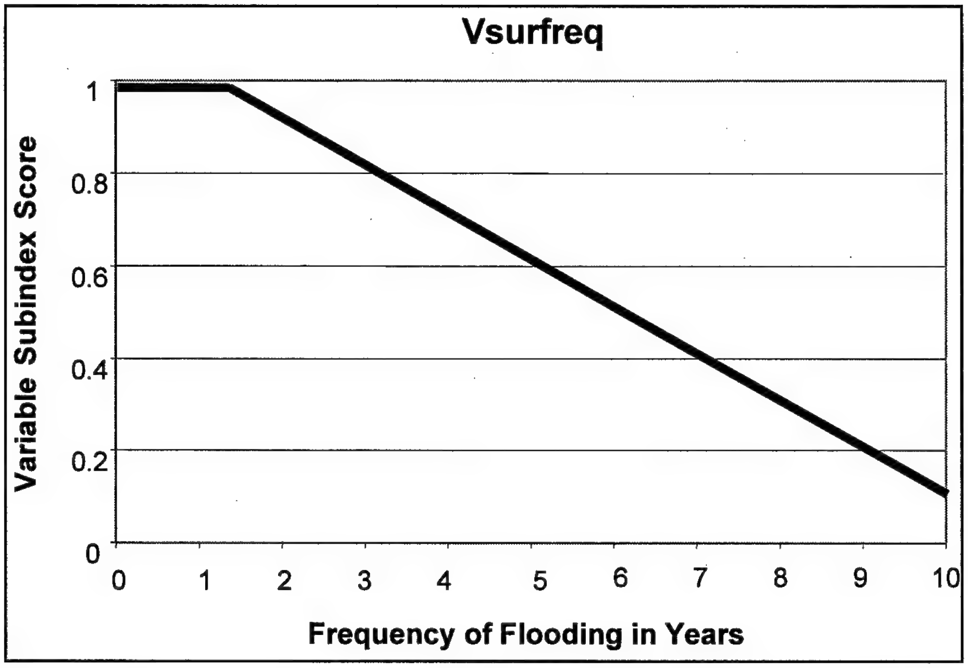


Figure 31. Function 6: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as a 0.0.

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8 based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

b. *Frequency of Subsurface Flooding ($V_{SUBFREQ}$).* The reference condition among northern Rocky Mountain river floodplains is marked by extensive subsurface flooding of disconnected side channels, meander scrolls, and fluvial depressions. The subsurface flooding primarily occurs via the preferential flow pathways established by the history of channel avulsion and the creation of paleochannels. Connectivity is so profound among reference standard floodplains that these systems flood

virtually every year with the spring snowmelt that characterizes the natural hydrographic regime of the Reference Domain. This variable is scaled at a frequency for subsurface flooding of each year at 1.0 and greater than 5 years as 0.1 (Figure 32). Entrenchment, channelization, dikes, and /or levees that restrict the movement of the main channel may result in loss of stage height during both floods and at base flow. The consequence is a reduction in the frequency of subsurface flooding, as well as a rapid dewatering of floodplain wetlands during midsummer months. These floodplains may also lose flooding if subsurface connections are broken or the river bottom becomes armored with fine sediments and entry points into the pathways of preferential flow are sealed. If modification to the floodplain through construction of levees or dikes, degradation of the river bed, or modification to the hydrologic regime is sufficient to hydrologically disconnect the river from the floodplain via subsurface flooding (e.g., up-stream high-head hydroelectric dam) the assessment team may conclude that subsurface flooding has been eliminated from the river. In such an instance, a variable subindex score of 0.0 is justified.

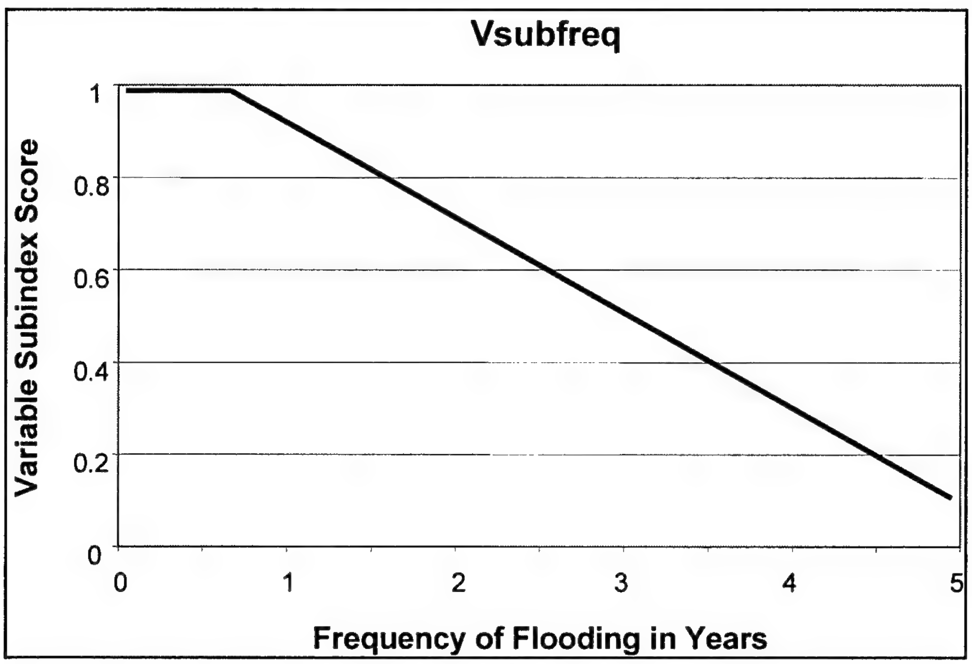


Figure 32. Function 6: Relationship of surface flood recurrence and the corresponding $V_{SUBFREQ}$ Variable Subindex Score

c. *Macrotopographic Complexity (V_{MACRO}).* This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools, and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, Macrotopographic (V_{MACRO}) Complexity is evaluated at the landscape spatial scale. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff years, and thus is integral to the description and characterization of

landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it is critical to both onsite and offsite effects of modification to the floodplain.

The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, evaluation should be based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photos.

This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 16).

Table 16
Function 6: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

d. *Proportionality of Landscape Features* ($V_{COMPLEX}$). This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because it operates at a landscape scale, by its very nature this variable extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. Descriptions are given in Chapter 5 (Assessment Protocols) for determining the appropriate size or area of floodplain to be assessed.

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 17 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/ floodplain complex can be described by a combination of conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and that often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and cover 15-25 percent of the surface area. Likewise, the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

Table 17
Function 6: Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect the Reference Standard Condition as a Condition that has been Significantly Impacted with Loss of Floodplain Complexity

	Variable Subindex Score								
Cover Type	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{SUBFREQ} + V_{MACRO} + V_{COMPLEX}}{4}\right)\right]$$

In the model equation that reflects the maintaining of a characteristic aquatic invertebrate food web, the function depends on the following factors: (1) frequency of surface flooding, (2) frequency of subsurface flooding, (3) macrotopographic complexity of the floodplain surface which provides the connectivity between the river channel and floodplain ponds, springbrooks, and other aquatic features, and (4) complexity of the various cover types of vegetation which along with instream primary production provides the organic matter that drives the food web.

Function 7: Characteristic Vertebrate Habitats

Definition. The function of maintaining Characteristic Vertebrate Habitats is defined as the capacity of the river floodplain-wetland complex to maintain the habitats necessary for a characteristic diversity and abundance of fish, herptiles (i.e., amphibians and reptiles), birds, and mammals. Many of the representatives of these vertebrate groups are extremely mobile with high variability in spatial and/or temporal use of floodplain wetlands. For example, migratory waterfowl and Neotropical birds are extremely temporal in their nature of the use of floodplains. In contrast, frogs, toads, and salamanders are far less mobile than birds and generally will remain on the floodplain throughout their lifetime. Likewise, very small mammals (e.g., voles, shrews) have relatively small home ranges, while large mammals that commonly use riverine floodplains and their associated wetlands (e.g., elk, deer, bear) may range over several kilometers in a single day. The consequence of high spatial and temporal variability among mammals is that direct measurement of species presence or absence is often impractical or misleading. Therefore, functional assessment protocols for this function are based on indicators of high-quality habitat for the various vertebrate species.

An independent measure of this function would include fish, amphibian, and bird surveys, including the various forms of habitat usage. Use of the floodplain by small mammals could be measured using live trap methods. Various forms of observation at particularly critical times of the year could verify large animal use. For example, elk use river floodplains of the Reference Domain as winter range and as calving grounds.

Rationale for Selecting the Function. River floodplains support a wide variety of vertebrates from fish to bears. In northern Rocky Mountain alluvial gravel-bed river floodplains, springbrooks and other wetland habitats provide essential habitat for spawning and rearing juveniles. It has also been clearly demonstrated that subsurface flow of water from the floodplain to the main channel forms essential habitat for spawning of bull trout (Baxter and Hauer 2000). Vertebrates function as primary consumers (e.g., grazers, browsers, seed eaters) and secondary consumers (carnivores). Likewise, some species are trophic generalists while others are highly specialized.

The diversity of terrestrial vertebrates within riverine-dominated landscapes appears to be closely associated with the diversity of habitat created by geomorphic, hydrologic, and vegetative diversity in structure and regimes. Thus, performance of this function is founded on the ecological interconnectivity between habitat complexity and support of the characteristic vertebrate fauna that typifies riverine floodplains and their associated wetlands in the northern Rocky Mountains. Habitat requirements are highly variable within and between species. The maintenance of a diverse vertebrate fauna is dependent on a diverse and productive habitat. Thus, the rationale of this function is based on the connectivity between a diverse and characteristic vertebrate fauna that, within the constraints of a rapid assessment, focus on the characteristics of habitat features and their distribution across spatial scales.

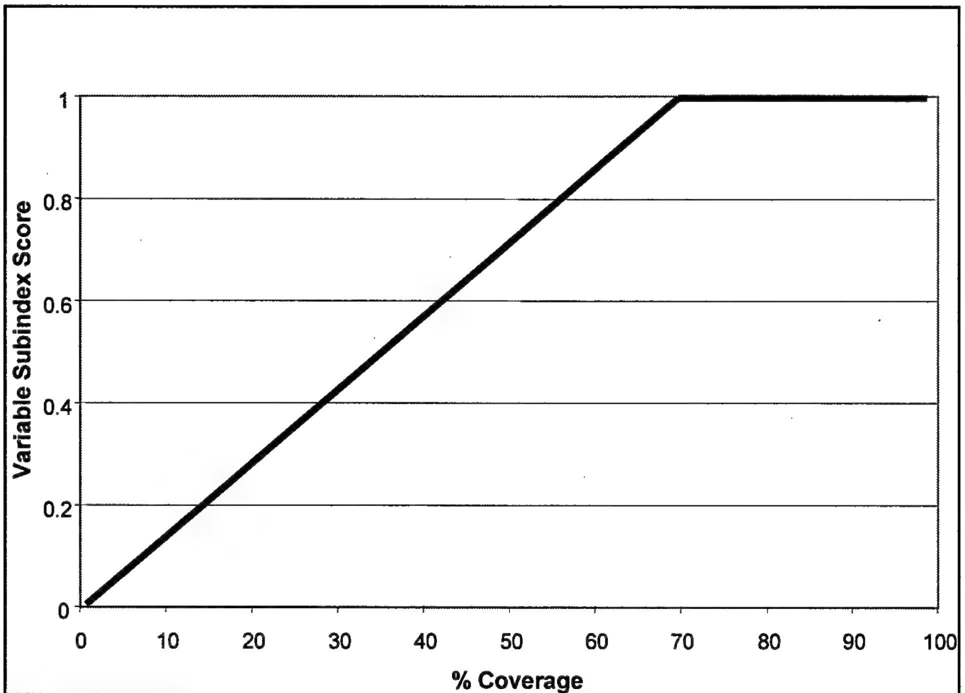
Characteristics and Processes that Influence the Function. There are many factors that affect the quality and quantity of vertebrate habitat across the plethora of habitats that characterize riverine floodplains. The fundamental drivers of floodplain structure and function (i.e., hydrology and geomorphology) greatly affect vertebrate response. For example, a temporarily flooded floodplain marsh that holds water throughout the spring and summer will possess not only significantly different vegetation from that of a springbrook or a temporarily flooded side channel, but will also be significantly different in support of aquatic habitats for various species, such as amphibian immature life stages. Thus, duration of flooding is an important variable that directly influences the characteristics and processes of this function. Likewise, the connectivity of water surfaces, particularly as influenced by the depth and duration of flooding, has a significant effect on fish access to floodplain habitats as well as the quality of those habitats for life cycle support. For example, small immature fish require permanent waters of sufficient depth and temperature to avoid predators and sustain appropriate metabolic rates.

Alterations of hydrographic regimes or geomorphic configuration affect the primary response variables expressed by the vegetation. The geomorphic alteration of the floodplain via levees, dikes, or other structures to either protect structures or land has been a significant source of river and river floodplain degradation. Landuse across the floodplain surface, particularly transportation corridors, construction of homes, and farming (e.g., cultivation, grazing by cattle, haying), has an effect on vertebrate habitat. Alterations of vegetation affect trophic structure and nutrient and energy flux that are integral to the trophic support of vertebrates.

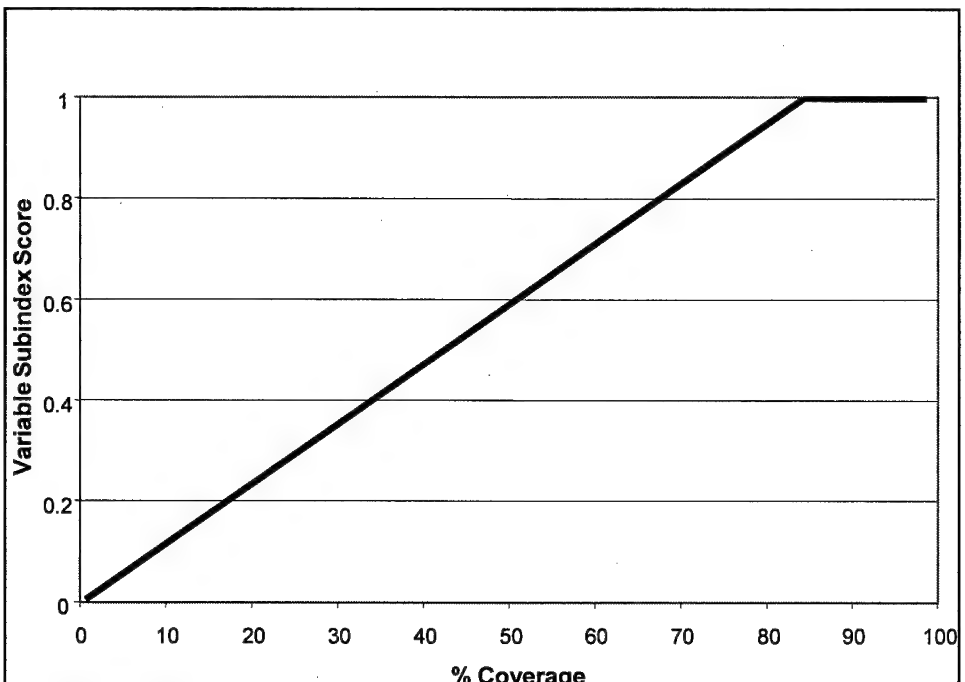
The vertebrate habitats on river floodplains are dependent on the quantity and quality of vegetation (V_{HERB}, V_{SHRUB}, V_{DTREE}, V_{NPCOV}). Typical densities of wildlife populations generally consume relatively small amounts of primary production on floodplains. In contrast, significant change in vegetation under heavy grazing pressure from cattle has been observed, which directly affects each of these vegetation variables. Vertebrate habitats are also directly affected by the frequency of surface flooding ($V_{SURFREQ}$), connectivity of habitats (V_{MACRO}), and the landscape complexity of the floodplain ($V_{COMPLEX}$) and its interconnectedness (V_{HABCON}).

Description of Model Variables.

a. Herbaceous Plant Coverage (V_{HERB}). This variable represents the percent coverage of herbaceous plants per unit area across the floodplain by cover type. The herbaceous layer is defined as all herbaceous grasses and forbes that do not have woody stems. The herbaceous coverage changes between cover types and is one of the first variables to respond to human disturbance on the floodplain. Herbaceous coverage is measured as the percent coverage within a 1-m by 1-m plot. If the shrub coverage is being estimated within Cover Types 1-4 (tree- and shrub-dominated cover types), then the herbaceous coverage should be estimated within the larger plots. Figure 33 presents the density of herbs expressed as percent coverage and the corresponding Variable Subindex Scores for each of the six cover types that are evaluated for this variable.

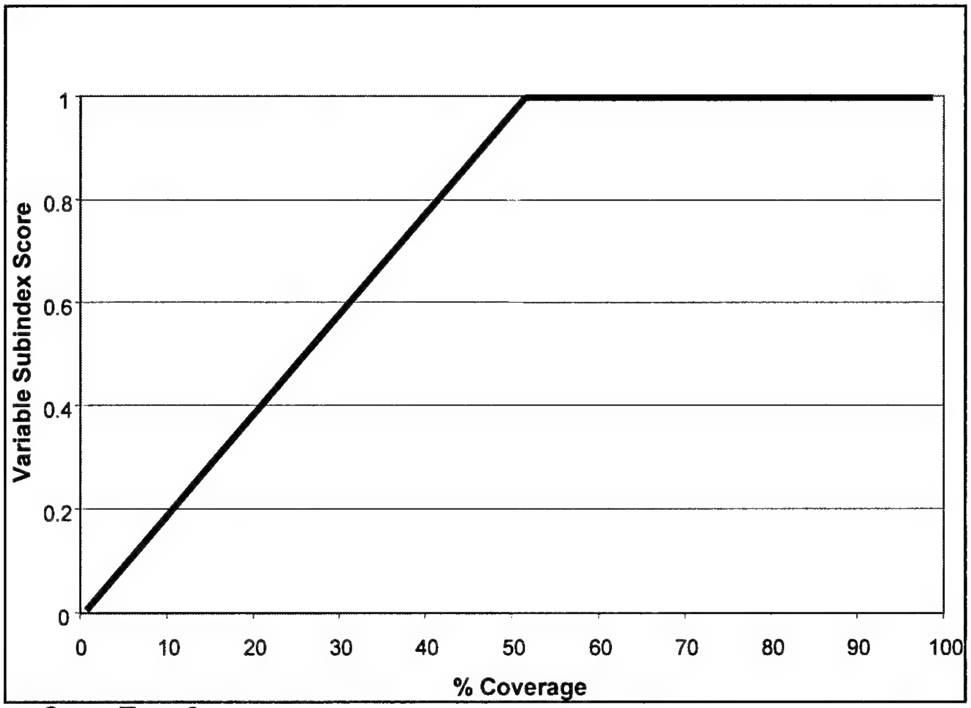


a. Cover Type 1

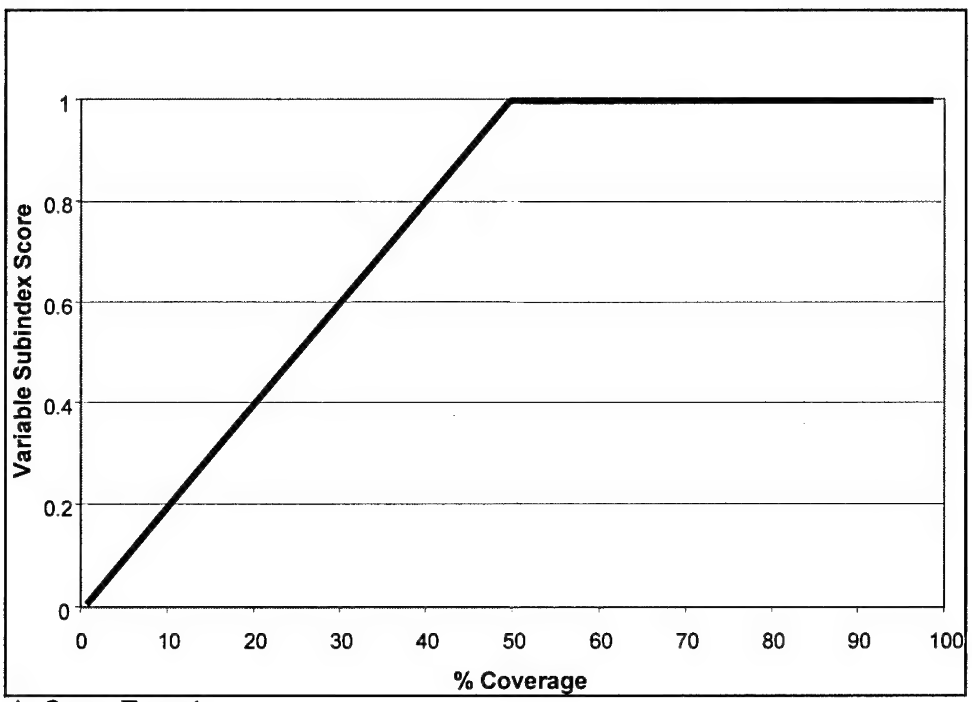


b. Cover Type 2

Figure 33. Function 7: Percent coverage of the herbaceous layer of plants and corresponding Variable Subindex Scores for Cover Types 1-6 (Sheet 1 of 3)

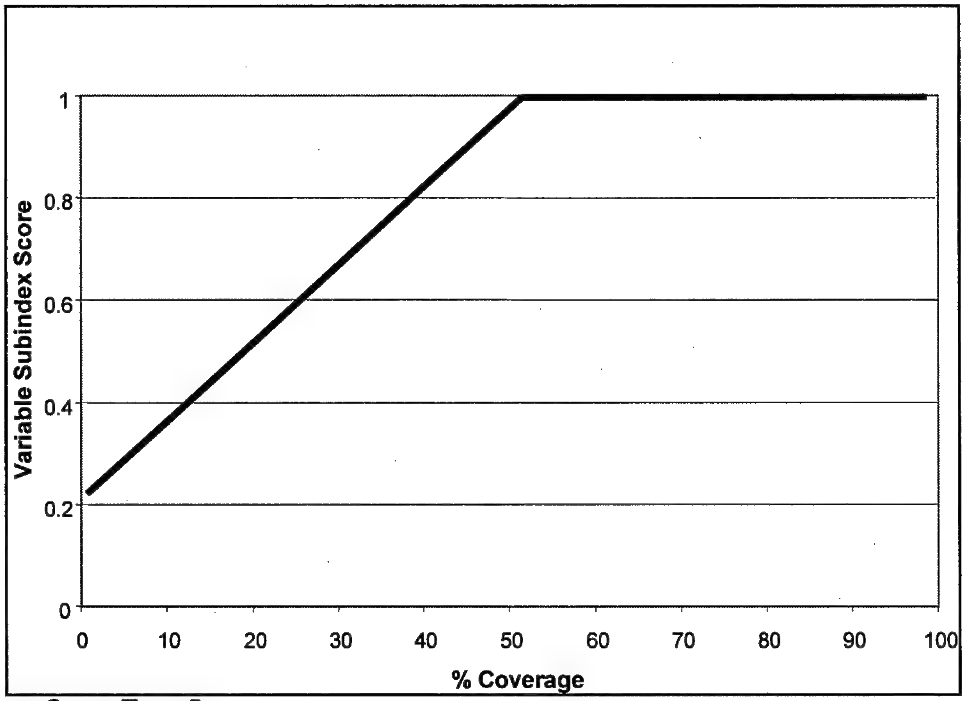


c. Cover Type 3

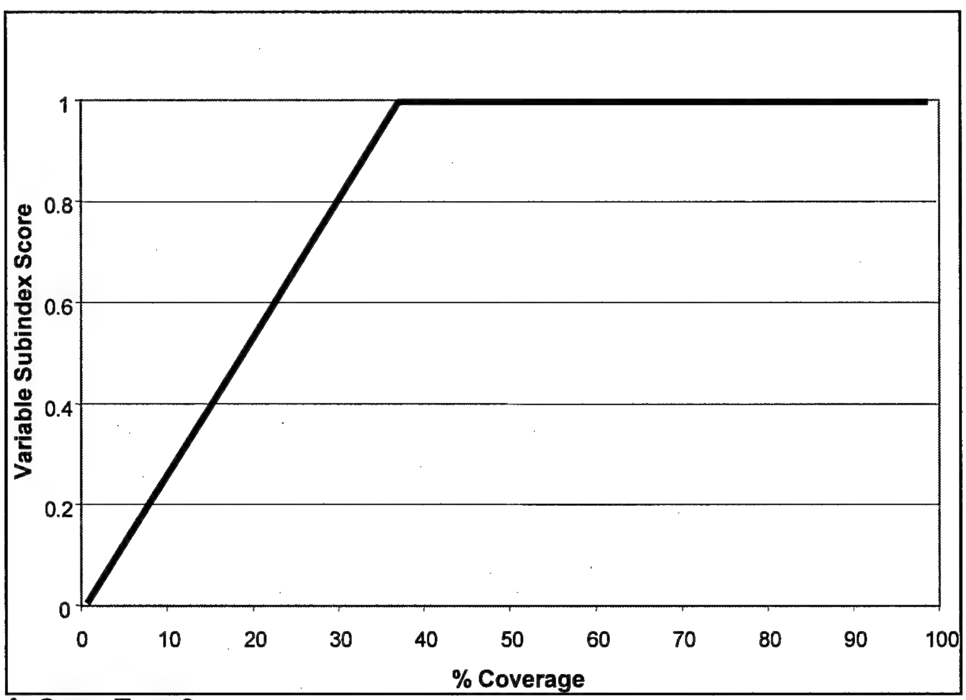


d. Cover Type 4

Figure 33. (Sheet 2 of 3)



e. Cover Type 5

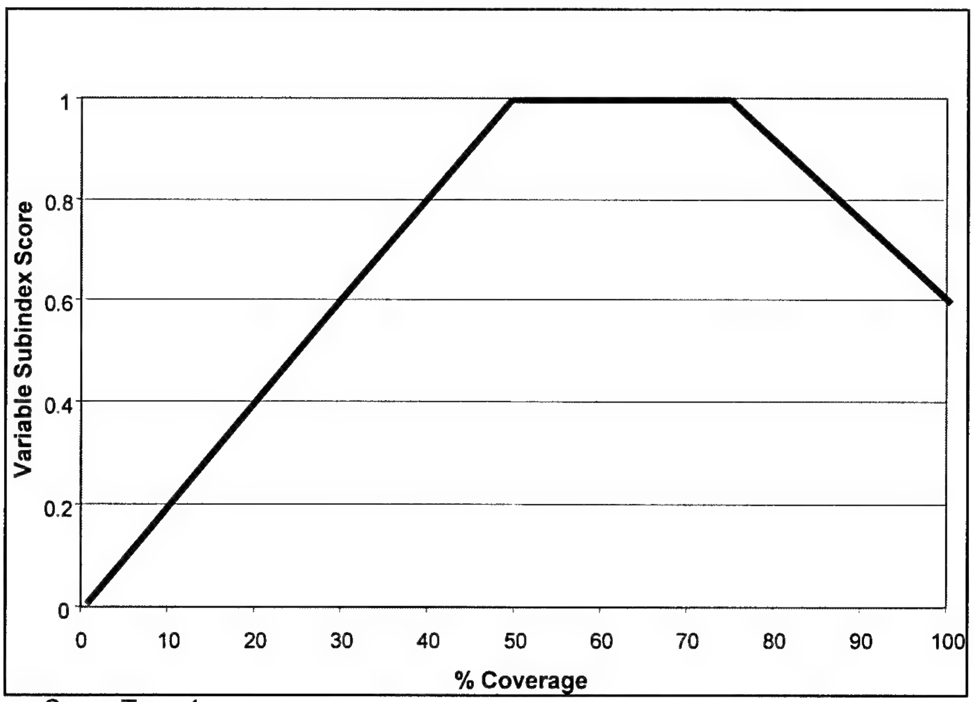


f. Cover Type 6

Figure 33. (Sheet 3 of 3)

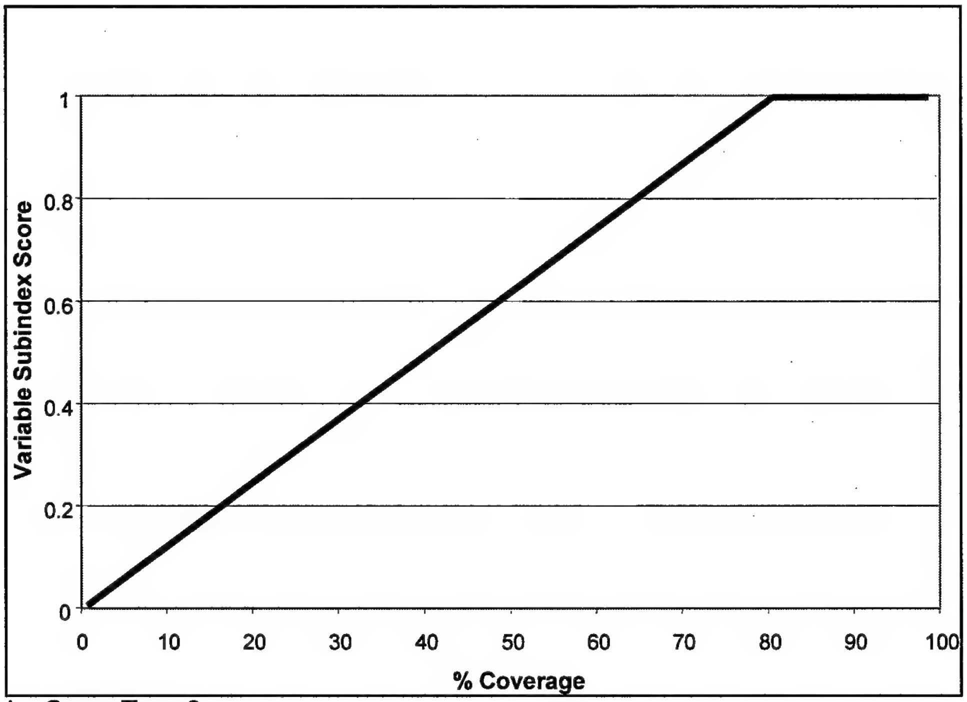
b. *Pole Cottonwood, Willow, Shrub, and Sapling Coverage (V_{SHRUB}).* This variable represents the percent coverage of shrubs and saplings per unit area across the forested and shrub-covered floodplain. Shrubs and saplings are defined as woody stems <6 m in height and <10 cm dbh. The shrub and sapling coverage changes among cover types. In the context of this variable, pole cottonwood, and willow, and shrub density is measured as a function of percent coverage rather than stem density because of the high variability among species.

Shrub coverage is measured as the percent coverage within a 5- by 5-m plot. If the shrub coverage is being estimated within Cover Types 1 and 2 (tree-dominated cover types), then the plot should be taken as one of the quarter sections of the tree density plots. Cover Type 3 and 4 plots are selected independently since the pole cottonwoods, saplings, and shrubs are the dominant woody species. It is common to encounter very narrow Cover Type 4 and 5 polygons as a result of fluvial processes on the floodplain and the subtle differences in elevation. When this occurs, plots should be extended in length and narrowed in width, yet a 25-m^2 plot should remain the standard plot size. Figure 34 presents the density of shrubs and saplings and the corresponding Variable Subindex Scores for each of the five cover types commonly having a major shrub component of the vegetation.

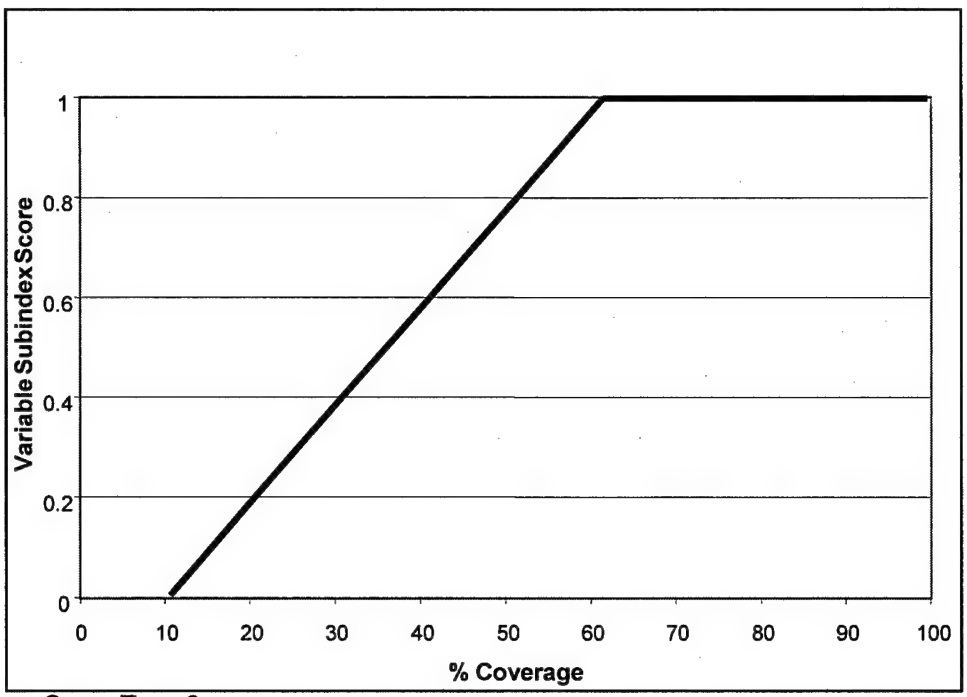


a. Cover Type 1

Figure 34. Function 7: Percent coverage of the shrub layer of plants and corresponding Variable Subindex Scores for Cover Types 1-5 (Sheet 1 of 3)

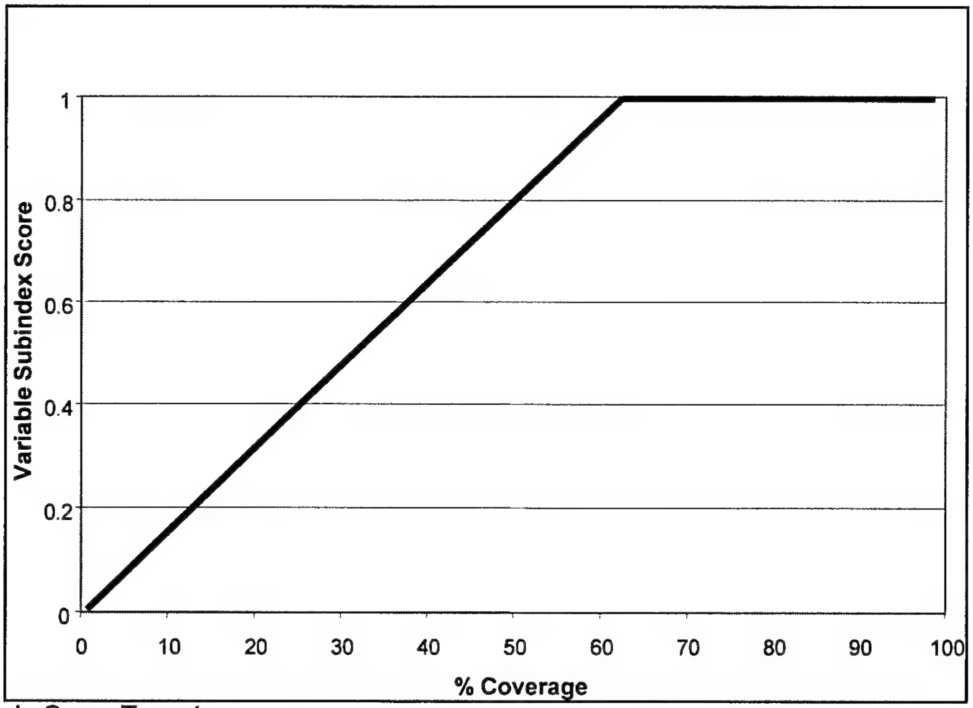


b. Cover Type 2

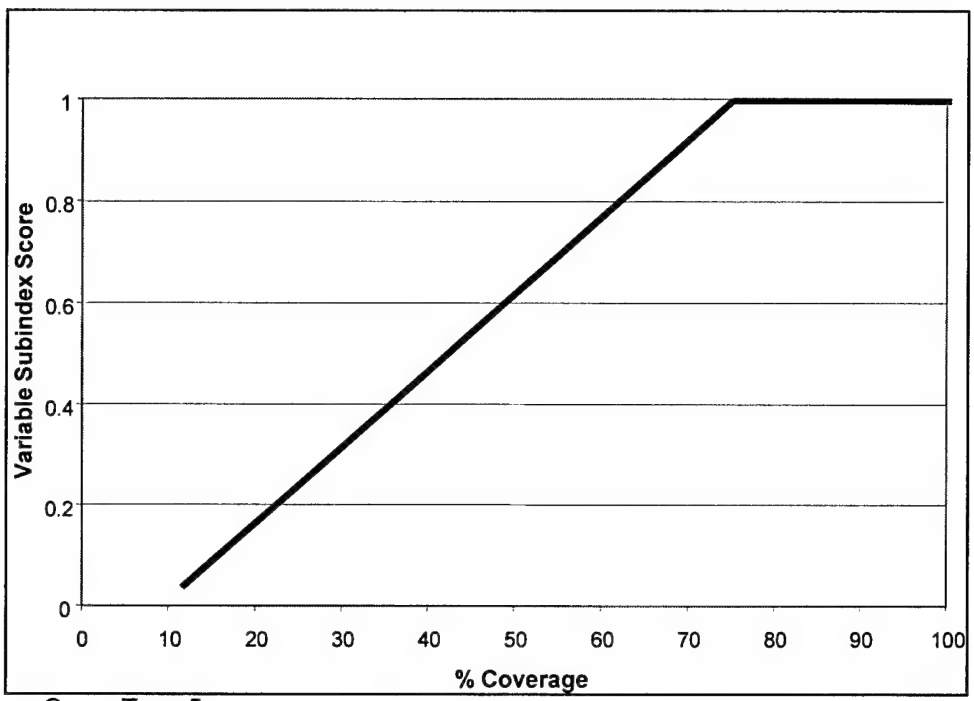


c. Cover Type 3

Figure 34. (Sheet 2 of 3)



d. Cover Type 4

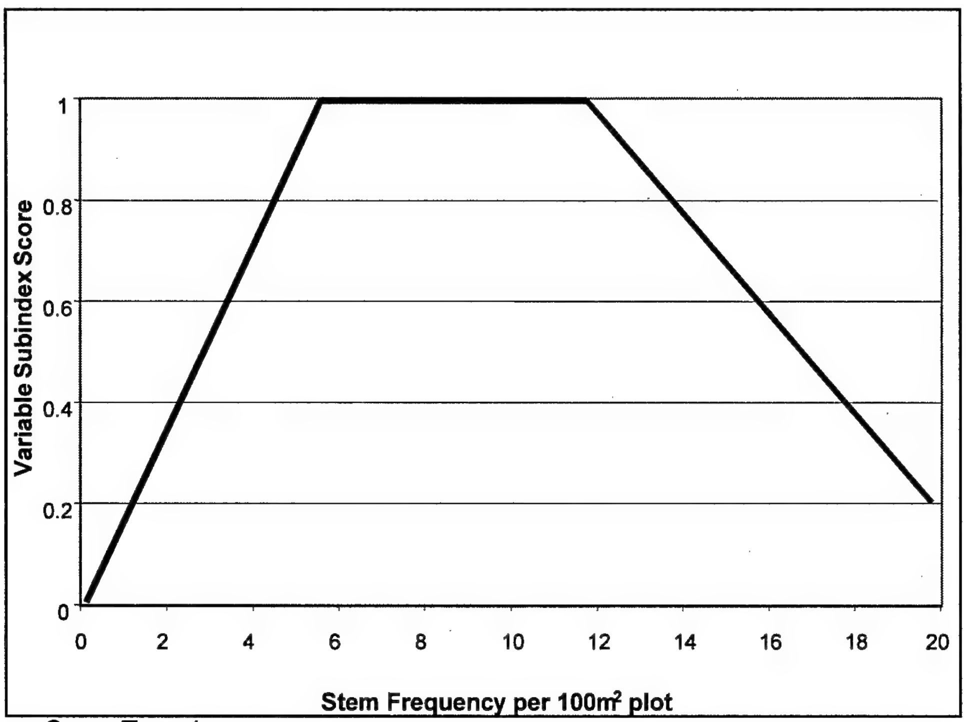


e. Cover Type 5

Figure 34. (Sheet 3 of 3)

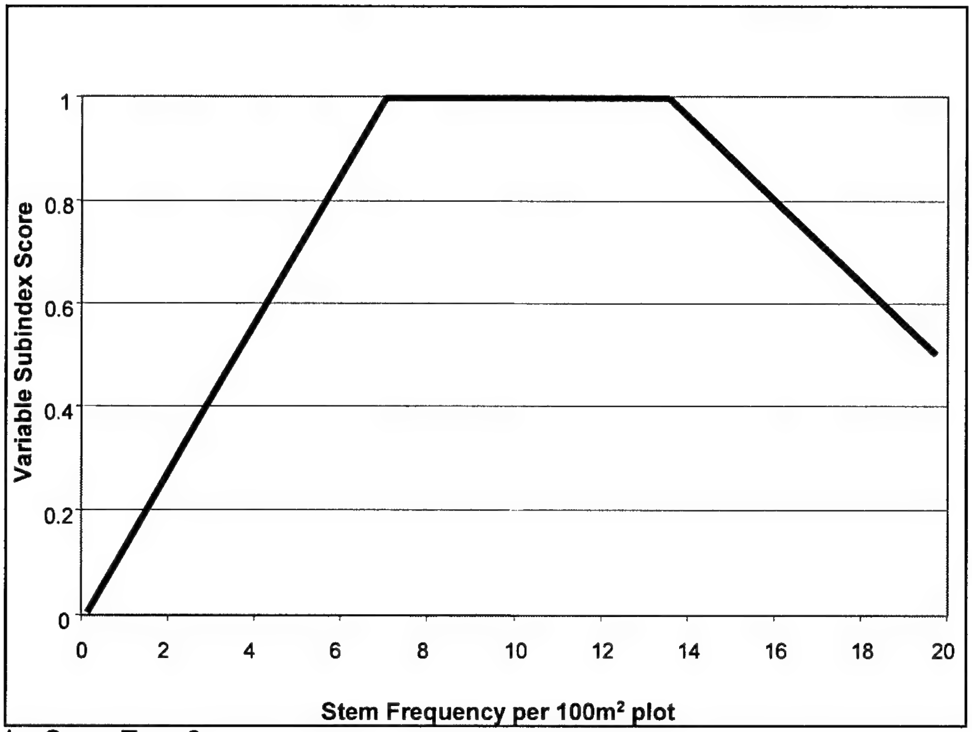
c. *Tree Density (V_{DTREE}).* This variable represents the number of trees per unit area across the forested cover types of the riparian floodplain wetlands. Trees are defined as woody stems ≥6 m in height or ≥10 cm dbh. In most forested systems, tree stem density and basal area increase rapidly during the early successional phases. This is also true in the northern Rocky Mountain floodplain systems. Thereafter, tree density decreases and basal area increases as the forest reaches mature steady-state conditions (Spurr and Barnes 1980). In the context of this function, tree density serves as an indicator of plant community structure.

This variable is measured by averaging the number of tree stems in a 10- by 10-m plot. If the density is low, the size of the plot should be increased, but the data should be relativized to number per 100 m^2. The number of sample plots required to adequately characterize the area being assessed will depend on its size and the heterogeneity of the forest within the cover type being evaluated; however, at least three plots in any one stand or floodplain polygon should be sampled, more if heterogeneity is high. The results from all plots should be averaged. Chapter 5 (Assessment Protocols) provides guidance for determining the number and layout of sample points and sampling units. Figure 35 presents the density of trees and the corresponding Variable Subindex Scores for the two cover types dominated by mature forest canopy trees.



a. Cover Type 1

Figure 35. Function 7: Tree stem density and corresponding Variable Subindex Scores for Cover Types 1 and 2 (Continued)



b. Cover Type 2

Figure 35. (Concluded)

d. *Percent Coverage by Native Plants (V_{NPCOV}).* Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) as well as animal populations are adapted to native plants for food, cover, nesting, etc. Non-native plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance. For example, tamarisk (salt cedar) is a major invader of river floodplains in the interior west, particularly where dams or diversions have altered the hydrographic regime. Likewise, spotted knapweed is an invader of disturbed areas that significantly competes with the native plant community.

This variable represents the weighted mean percent coverage of native plants within each vegetation cover type on the floodplain. The concept and calculation of this variable is a measure of the percent coverage by all native plants. This variable is calculated by estimating the Variable Subindex Score for each vegetation layer and each cover type (Figure 36) and weighting that score by the percent of each cover type within the Assessment Area.

e. *Frequency of Surface Flooding ($V_{SURFREQ}$).* The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull condition is surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of 10 years). However, the various habitats of a floodplain also exhibit

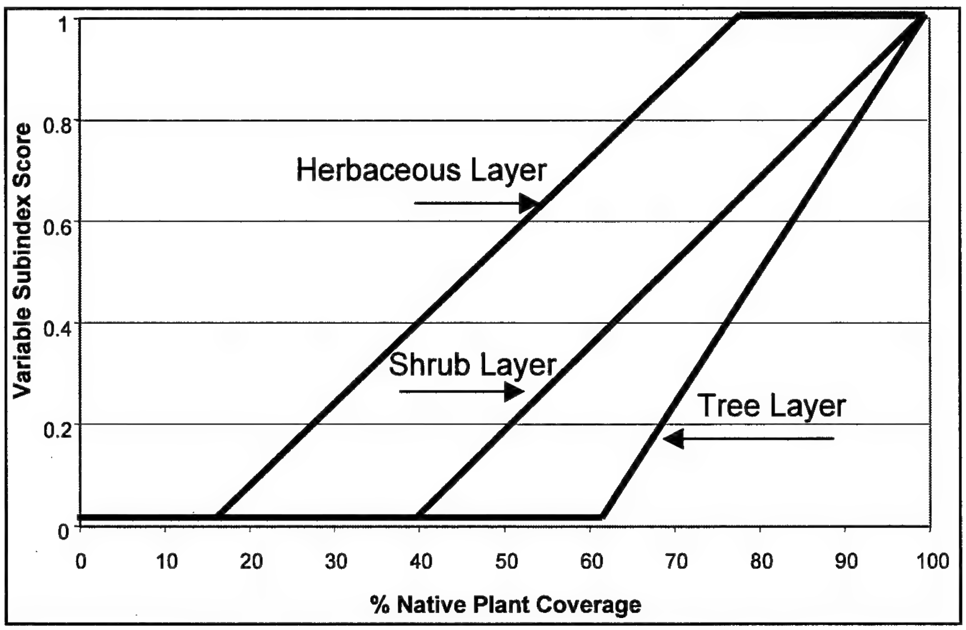


Figure 36. Function 7: Correlation between percent Native Plant Cover and corresponding Variable Subindex Scores by vegetation layer

different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 37). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleochannels flood at a frequency >10 years, then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as 0.0.

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8, based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

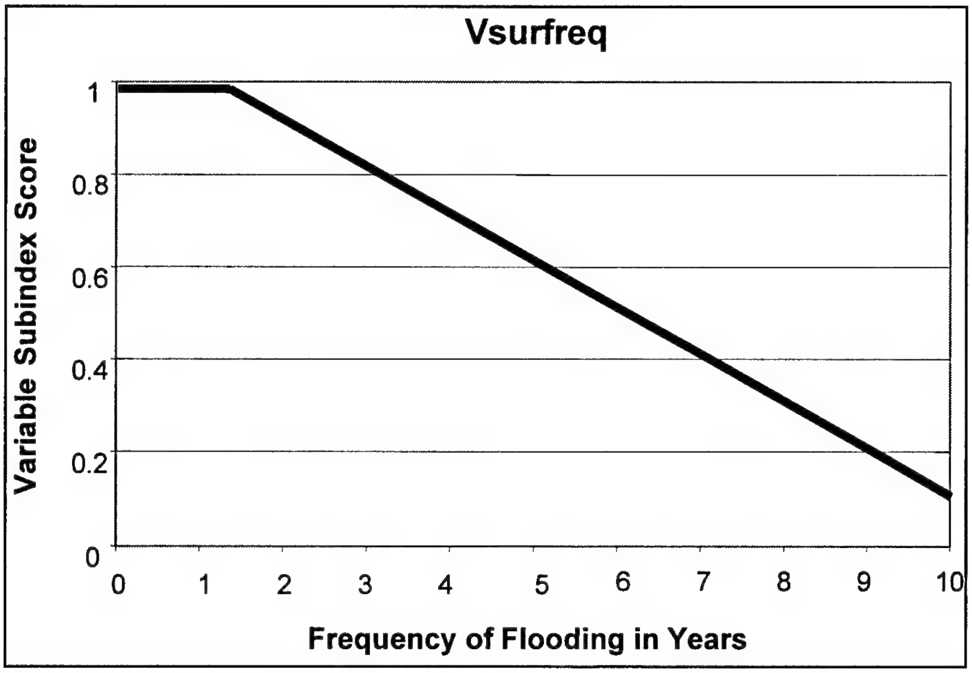


Figure 37. Function 7: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

f. *Macrotopographic Complexity (V_{MACRO}).* This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools, and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, Macrotopographic (V_{MACRO}) Complexity is evaluated at the landscape spatial scale. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff years and thus is integral to the description and characterization of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it is critical to both onsite and offsite effects of modification to the floodplain.

The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, evaluation should be based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photos.

This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 18).

Table 18
Function 7: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

g. *Proportionality of Landscape Features ($V_{COMPLEX}$).* This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. See the descriptions given in Chapter 5 (Assessment Protocols) for determining the appropriate size or area of the floodplain to be assessed.

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 19 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/floodplain complex can be described by a combination of conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and that often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and covers 15-25 percent of the surface area. Likewise, the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

Table 19
Function 7: Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect the Reference Standard Condition as a Condition that has been Significantly Impacted with Loss of Floodplain Complexity

Cover Type	Variable Subindex Score								
	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

h. *Floodplain Habitat Connectivity (V_{HABCON}).* This variable describes the connectivity of floodplain habitats between the surface and subsurface, between and among surface wetland features, and between the wetlands and surrounding upland riparian areas. Connectivity of aquatic habitats between the channel and the floodplain is essential for the movement of aquatic organisms that dominate the hyporheic zone as well as organisms that generally are found in groundwater discharge zones on the floodplain (e.g., springbrooks and wetlands).

This is an important landscape scale variable that describes the inter-relationship among the various floodplain habitats including intermittently flooded terraces on the floodplain. In the Reference Standard condition, mixed conifer and cottonwood forests occupy over 50 percent of the intermittently flooded terraces. Disturbed floodplain complexes have a significantly reduced forest, increased pasture, or replacement by domestic or commercial development. Table 20 presents a series of approximate ranges of the various cover types and the extent of connectivity between the main river channel, paleochannels, springbrooks, and fluvial depressions that commonly occur under different levels of impact.

Table 20 **Function 7: Habitat Connectivity and Linear Linkages Between Riparian Habitats in the Form of Movement Corridors Between Cover Types as Well as Floodplain Lentic and Lotic Habitats and Corresponding Variable Subindex Scores**	
Description	**Score**
Cover Types 1- 4 occupy 50-80% of area with well-developed connections between patches. Side channels, back and side channels, and floodplain scour pools and ponds well connected to main channel annually. Ponds not connected during base flow, thus permitting isolation for some species. No evidence of floodplain modification either increasing or decreasing connectivity.	1.0
Cover Types 1-4 occupy 25-50% of area with moderately well-developed connections between patches. Occasionally Cover Type 1-3 patches isolated. Side channels, paleochannels, and floodplain scour pools and ponds well connected to main channel 1 in 5 years. Either increased or decreased connectivity due to floodplain modification.	0.8
Cover Types 1-4 occupy 10-25% of area with poorly developed connections between patches. At least 50 percent of Cover Type 1-3 patches isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds connected to main channel only in very high discharge years (1 in 25 to 50 years).	0.6
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds never connected to main channel.	0.4
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds are never connected and entering later stages of senescence.	0.2
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >25% of total area but less than 50%. Interconnectivity between floodplain wetlands and the main channel greatly reduced.	0.1
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >50% of total area. Interconnectivity between floodplain wetlands and the main channel absent.	0

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE} + V_{NPCOV}}{4} \right) \times \left(\frac{V_{SURFREQ} + V_{MACRO} + V_{COMPLEX} + V_{HABCON}}{4} \right) \right]^{1/2}$$

In the model equation, maintain characteristic vertebrate habitat, the function depends on the following factors: (1) the herbaceous plant communities, (2) the shrub layer of the plant communities, (3) the tree layer of the plant communities, (4) the proportion native plant coverage, (5) the frequency of surface flooding, (6) the macrotopographic relief, (7) the proportionality of the landscape complex, and (8) the connectivity of vegetated corridors. In the first part of the equation, V_{HERB}, V_{SHRUB}, V_{DTREE}, and V_{NPCOV} are all critical measures of the vegetation communities and native plant coverages. The equation expresses these four variables as an arithmetic mean. The second part of the equation represents the frequency of flooding $V_{SURFREQ}$, the macrotopographic complexity V_{MACRO} that is necessary to maintain aquatic connectivity, measures of floodplain complexity, $V_{COMPLEX}$, which is a metric of cover type frequency and abundance, and finally the connectivity of those cover types through direct connections or corridors used

by large mammals and birds, V_{HABCON}. The equation expresses these four variables as an arithmetic mean. These two separate parts are placed within the context of the geometric mean.

Function 8: Floodplain Interspersion and Connectivity

Definition. The function of maintaining characteristic Floodplain Interspersion and Connectivity is defined as the maintenance of landscape features of habitat interspersion and connectivity between the river, its floodplain wetlands, and the surrounding floodplain habitats composed of lentic and lotic environments. Relatively high-energy rivers that course through cobble substrata dominate large river floodplains of the northern Rocky Mountains. A mosaic of surfaces that include jurisdictional and nonjurisdictional wetland habitats that are strongly interspersed and interconnected characterizes these floodplains. These floodplain surfaces are underlain by subsurface variability in substratum material that has been sorted into zones of high and low hydrologic conductivity.

An independent measure of this function would include detailed analysis of floodplain habitats based on digital aerial photographic series that have been geo-rectified and digitized using specific analysis criteria.

Rationale for Selecting the Function. It is essential that those conducting a functional assessment of alluvial floodplain wetlands understand that the interspersion and connectivity of habitats across the floodplain surface are integral to the function of these systems. Thus, it is virtually impossible to mitigate for wetland losses in a regulatory sense without reconstructing or mitigating for this interspersion and connectivity.

Wildlife ecologists have generally assumed that most important ecological processes that affect populations and communities operate at localized spatial scales. However, there has been increased recognition over the past decade that habitat variation has a profound influence on wildlife and operates at multiple spatial scales. The decline of many species has been linked directly to habitat loss and fragmentation. To capture this concept, we have included the role of floodplain function within a landscape context.

Structural connectivity varies along a continuum and is the inverse of the proportion of linkages that must be added to have a connected system (Forman and Godron 1986), in which the fewer the gaps in habitat continuity, the higher the population connectivity. Functional or behavioral connectivity refers to how connected an area is for a process, such as an animal moving through different types of landscape elements (i.e., interspersion). Thus, this function is quantified and scaled after land-use patterns that affect flows and movements across the landscape or between floodplain habitats. Potential independent quantitative measures for validating the functional index include patch-centered measures (e.g., isolation of patch, accessibility of patch, dispersion of patches, and nearest neighbor probabilities (Forman and Godron 1986).

Characteristics and Processes that Influence the Function. This function is largely founded on the premise that the patterning of landscape elements (i.e., riverine floodplains and their associated wetlands) strongly influences ecological relationships. This function focuses on the relative role of land use in and around the wetland and on landscape features, particularly habitat connectivity and the proportionality of floodplain surfaces and habitats across the landscape mosaic. Most vertebrates not only require food resources to sustain populations, but also require structural habitat and cover associated with predator avoidance, nesting, resting, etc. Populations also require exchange of genetic material between metapopulations to maintain long-term viability. To maintain these vital associations, vertebrate populations that use river floodplains to complete some portion of their life histories need to be able to move between neighboring habitats. Whereas Function 7 focused on the quality of habitats, this function focuses on the connectivity and interspersion (i.e., distribution) of these habitats, among both permanently flooded habitats (e.g., ponds, springbrooks) and intermittently flooded habitats (e.g., cottonwood stands). Thus, various landscape features have a significant affect on the connectivity and interspersion of these landscape patches. For example, a floodplain terrace that is a cultivated field or pasture that has been intensively grazed may lack the habitat structure necessary for terrestrial vertebrates to move freely between adjacent habitats. Likewise, birds may lack the cover necessary to raise broods or move easily with their young. Geomorphic modification of the floodplain in particular has a significant effect that alters surface flooding and eventually subsurface flooding. Losses of this nature result in a disconnection between the river and its floodplain that affect both the river and floodplain habitats in deleterious ways that are manifest in losses in production, species complexity, and diversity.

Description of Model Variables.

a. *Proportional Land Use ($V_{LANDUSE}$).* This variable is a function of the various land uses and their relative impact on the floodplain. The calculation of this variable is based on the general land use within each cover type in the WAA and thus must be evaluated onsite. Frequently a single land use will extend over an entire WAA. However, when land use changes from polygon to polygon or from one side of the WAA to the other, as may occur for example when a WAA is divided along a fence line or is affected by a road, then the different land uses are scored according to the area they occupy. Table 21 presents a series of commonly occurring land uses within the Reference Domain.

The Variable Subindex Score, as described in Table 21, is applied to each affected polygon within the WAA and is applied proportionally to each polygon based on the summation of scores as described above.

b. *Floodplain Habitat Connectivity (V_{HABCON}).* This variable describes the connectivity of floodplain habitats between the surface and subsurface, between and among surface wetland features, and between the wetlands and surrounding upland riparian areas. Connectivity of aquatic habitats between the channel and the floodplain are essential for the movement of aquatic organisms that dominate the hyporheic zone, as well as

Table 21
Function 8: Calculation Table of Current Land Use and the Corresponding Variable Subindex Scores for Many of the Prevalent Land Uses Encountered on River Floodplains Across the Northern Rocky Mountains

Current Landuse	Score
Commercial right-of-way, with or without paving, road or parking lot	0.0
Domestic or commercially developed with buildings	0.0
Gravel pit operation	0.0
Unpaved, private right-of-way (e.g., driveway, tractor trail)	0.1
Tilled crop production	0.2
Heavy grazing by livestock	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Seasonally used for wintering livestock	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Wildlands or managed for native vegetation coverage and diversity	1.0

organisms that generally are found in groundwater discharge zones on the floodplain (e.g., springbrooks and wetlands).

This is an important landscape scale variable that describes the interrelationship among the various floodplain habitats including intermittently flooded terraces on the floodplain. In the Reference Standard condition, mixed conifer and cottonwood forests occupy over 50 percent of the intermittently flooded terraces. Disturbed floodplain complexes have a significantly reduced forest, increased pasture or replacement by domestic or commercial development. Table 22 presents a series of approximate ranges of the various cover types and the extent of connectivity between the main river channel, paleochannels, springbrooks, and fluvial depressions that commonly occur under different levels of impact.

c. *Proportionality of Landscape Features ($V_{COMPLEX}$).* This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands. Because it operates at a landscape scale, by its very nature this variable extends beyond the Wetland Assessment Area and considers offsite effects. The area that should be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently delineated by upstream as well as downstream geomorphic knickpoints. Descriptions are given in Chapter 5 (Assessment Protocols) for determining the appropriate size or area of floodplain to be assessed.

Table 22
Function 8: Habitat Connectivity and Linear Linkages Between Riparian Habitats in the Form of Movement Corridors Between Cover Types as Well as Floodplain Lentic and Lotic Habitats and Corresponding Variable Subindex Scores

Description	Score
Cover Types 1-4 occupy 50 - 80% of area with well-developed connections between patches. Side channels, back and side channels, and floodplain scour pools and ponds well connected to main channel annually. Ponds not connected during base flow, thus permitting isolation for some species. No evidence of floodplain modification either increasing or decreasing connectivity.	1.0
Cover Types 1-4 occupy 25 - 50% of area with moderately well-developed connections between patches. Occasionally Cover Type 1-3 patches isolated. Side channels, paleochannels, and floodplain scour pools and ponds well connected to main channel 1 in 5 years. Either increased or decreased connectivity due to floodplain modification.	0.8
Cover Types 1-4 occupy 10- 25% of area with poorly developed connections between patches. At least 50% of Cover Type 1-3 patches isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds connected to main channel only in very high discharge years (1 in 25 to 50 years).	0.6
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds never connected to main channel.	0.4
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds are never connected and entering later stages of senescence.	0.2
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >25% of total area but less than 50%. Interconnectivity between floodplain wetlands and the main channel greatly reduced.	0.1
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >50% of total area. Interconnectivity between floodplain wetlands and the main channel absent.	0

It is virtually impossible to account for all possible combinations of cover types (see Table 7) and their percentages; however, Table 23 presents a series of approximate ranges of the various cover types as they commonly occur under different levels of impact. The Reference Standard wetland/ floodplain complex can be described by a combination of conifer and cottonwood forest at advanced stages of maturity that cover 50 to 75 percent of the floodplain surface area. The Reference Standard is also characterized by a complexity of side channels that are flooded annually and that often contain early seral stages of cottonwood, willow, and/or herbaceous vegetation and cover 15-25 percent of the surface area. Likewise, the Reference Standard floodplain has a well-developed cobble riverbed that is exposed at base flow and is generally 2-3 times the surface area of the channel surface at base flow. The Reference Standard contains no agricultural fields, domestic or commercial buildings, or transportation corridors.

d. *Frequency of Surface Flooding* ($V_{SURFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by spatial and temporal variation in the frequency of surface flooding. The normal frequency of recurrence for the main-channel bankfull condition is surface flooding approximately every 1.1 to 1.3 years (i.e., ~9 out of

Table 23
Function 8: Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect the Reference Standard Condition as a Condition that has been Significantly Impacted with Loss of Floodplain Complexity

	Variable Subindex Score								
Cover Type	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

10 years). However, the various habitats of a floodplain also exhibit different heights relative to base flow and/or bankfull flooding. This variable is scored based on the frequency of flooding from the main channel into side channels and paleochannels. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals beginning at 1.3 years (Figure 38). Longer recurrence intervals are assigned decreasing subindex scores to 0.1 at a recurrence interval of 10 years. If the side channels and paleochannels flood at a frequency >10 years, then the floodplain should be scored at 0.1. If the floodplain side channels and paleochannels never flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as 0.0.

In the reference standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8, based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

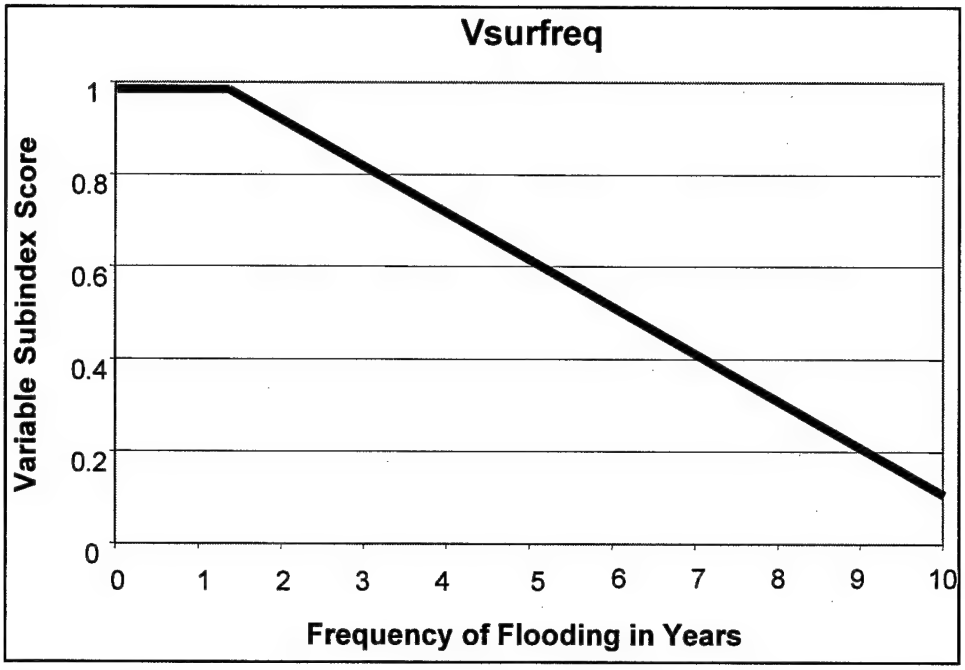


Figure 38. Function 8: Relationship of surface flood recurrence and the corresponding $V_{SURFREQ}$ Variable Subindex Score

e. Frequency of Subsurface Flooding ($V_{SUBFREQ}$). The reference condition among northern Rocky Mountain river floodplains is marked by extensive subsurface flooding of disconnected side channels, meander scrolls, and fluvial depressions. The subsurface flooding primarily occurs via the preferential flow pathways established by the history of channel avulsion and the creation of paleochannels. Connectivity is so profound among reference standard floodplains that these systems flood virtually every year with the spring snowmelt that characterizes the natural hydrographic regime of the Reference Domain. This variable is scaled at a frequency for subsurface flooding of each year at 1.0 and greater than 5 years as 0.1 (Figure 39). Entrenchment, channelization, dikes, and /or levees that restrict the movement of the main channel may result in loss of stage height during both floods and at base flow. The consequence is a reduction in the frequency of subsurface flooding, as well as a rapid dewatering of floodplain wetlands during midsummer months. These floodplains may also lose flooding if subsurface connections are broken or the river bottom becomes armored with fine sediments and entry points into the pathways of preferential flow are sealed. If modification to the floodplain through construction of levees or dikes, degradation of the river bed, or modification to the hydrologic regime is sufficient to hydrologically disconnect the river from the floodplain via subsurface flooding (e.g., up-stream high-head hydroelectric dam), the assessment team may conclude that subsurface flooding has been eliminated from the river. In such an instance, a variable subindex score of 0.0 is justified.

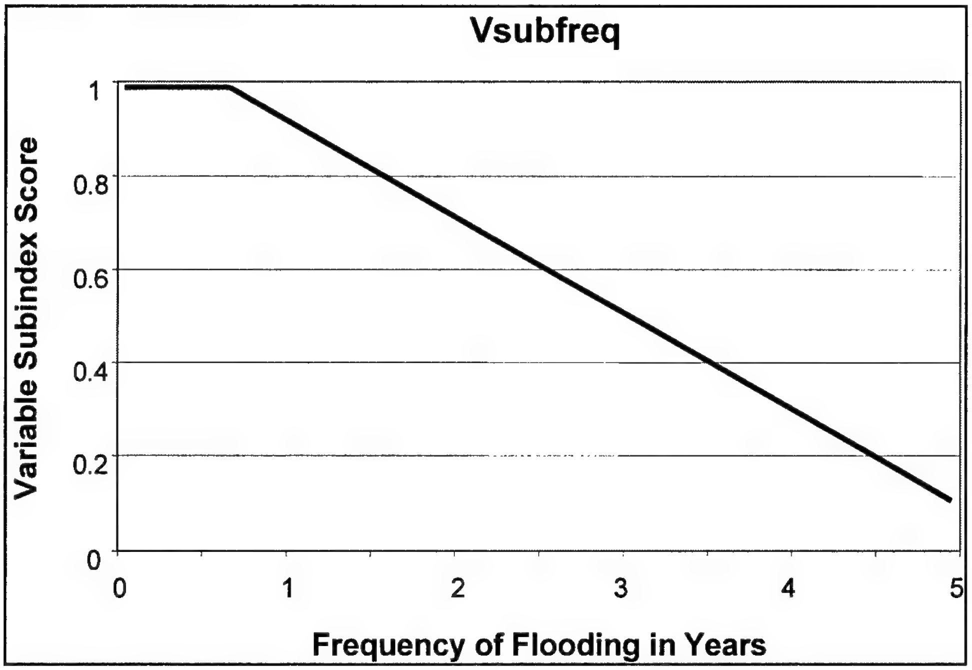


Figure 39. Function 8: Relationship of surface flood recurrence and the corresponding $V_{SUBFREQ}$ Variable Subindex Score

f. *Macrotopographic Complexity (V_{MACRO}).* This variable specifically describes the distribution and relative abundance of channels and connectivity between the main river channel, side channels, floodplain scour pools, and other floodplain features. Like $V_{SURFREQ}$ and $V_{SUBFREQ}$, Macrotopographic (V_{MACRO}) Complexity is evaluated at the landscape spatial scale. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low runoff years, and thus is integral to the description and characterization of landscape quality and the setting of the floodplain wetlands. Because this variable operates at a landscape scale, by its very nature it is critical to both onsite and offsite effects of modification to the floodplain.

The area to be evaluated for this variable depends on the hydrogeomorphic character of the floodplain being assessed. As discussed in Chapter 3, floodplains are frequently bounded hydrogeomorphically by upstream and downstream geologic knickpoints. To appropriately capture this variable, evaluation should be based on a combination of both aerial photographs and onsite verification of what is initially evaluated from the photographs.

This is an important landscape scale variable that describes the potential interconnectivity of surface flow and surface water storage (Table 24).

Table 24
Function 8: Macrotopographic Complexity and Corresponding Variable Subindex Scores Across the Floodplain Surface Including Linear Linkages Between the Main Channel and Other Floodplain Aquatic Habitats in the Form of Movement Corridors Between the Main Channel and Floodplain Wetland Habitats

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10-yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

g. *Geomorphic Modification (V_{GEOMOD}).* This variable represents the anthropogenic modification of the floodplain's geomorphic properties through modifications to control the river channel. Examples of geomorphic modification commonly practiced are riprap, revetment, dikes, levees, bridge approaches, and roadbeds. Each of these man-made structures function to preclude the movement of water from the channel onto the floodplain. Geomorphic modification on riverine floodplains that directly affect riparian wetlands has been used in the past to confine the river to protect property for domestic, commercial, or agricultural purposes.

The modification to the floodplain is geomorphic in nature, but directly affects hydrologic properties. Reveting, filling, mining, dredging, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated for each cover type polygon described within an Assessment Area. Offsite effects of geomorphic modifications may be extensive. The Assessment Team is advised to proceed cautiously in determining the scope of this variable, both within and adjacent to the Assessment Area. Table 25 presents a series of approximate ranges of the various types and extent of geomorphic modification between the main river channel, paleochannels, and floodplain terraces that commonly occur under different levels of impact.

Functional Capacity Index. The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{LANDUSE} + V_{HABCON} + V_{COMPLEX}}{3}\right) \times \left(\frac{V_{MACRO} + V_{SURFREQ} + V_{SUBFREQ}}{3}\right) \times V_{GEOMOD}\right]^{1/3}$$

Table 25
Function 8: Calculation Table of Variable Subindex Scores Based on Unaltered and Altered Geomorphic Conditions on the Floodplain

Description	Score
No geomorphic modifications (e.g., dikes, levees, riprap, bridge approaches, road beds, etc.) made to contemporary (Holocene) floodplain surface.	1.0
Few changes to the floodplain surface with little impact on flooding. Changes restricted to < 1 m in elevation and only for farm roads or bridges with culverts maintained. Geomorphic modifications do however result in minor change in cut-and-fill alluviation.	0.75
Modification to the floodplain surface < 1 m in elevation. Riverbank with control structures (e.g., riprap) < 10% of river length along LAA. Geomorphic modifications result in measurable change in cut-and-fill alluviation.	0.5
Multiple geomorphic modifications to the floodplain surface to control flood energy, often with bank control structures, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in significant reduction in cut-and-fill alluviation.	0.25
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure or constructed to prevent channel avulsion, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in termination of cut-and-fill alluviation.	0.1
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure preventing channel avulsion and also preventing flow access via culverts to backwater and side channels	0

In the model equation, maintain characteristic vertebrate habitat, the function depends on the following factors: (1) the land use across the floodplain, (2) the habitat connectivity, (3) the proportionality of the landscape complex, (4) the macrotopographic relief, (5) the frequency of surface flooding, (6) the frequency of subsurface flooding, and (7) geomorphic modifications that have been made to the floodplain. The first part of the equation is composed of the proportional land uses distributed across the floodplain ($V_{LANDUSE}$), the habitat connectivity (V_{HABCON}), and measures of floodplain complexity ($V_{COMPLEX}$). The equation expresses these three variables as an arithmetic mean. The second part of the equation represents the macrotopographic features that form flow pathways on the floodplain surface (V_{MACRO}), the frequency of surface flooding ($V_{SURFREQ}$), and the frequency of subsurface flooding ($V_{SUBFREQ}$). The equation expresses these three variables as an arithmetic mean. The third part of the equation is the geomorphic modification, V_{GEOMOD}, as a single variable. These three separate parts are placed within the context of the geometric mean.

5 Assessment Protocols

Assessment Protocol Overview

The previous chapters of this guidebook have presented: (a) background information on the HGM Approach, (b) wetland variables that are indicators of the level of function, (c) assessment models consisting of the indicator variables, and (d) an explanation of how those indicators and models are used to describe level of function. This chapter provides the specific office and field protocols that should be followed to conduct a complete HGM Functional Assessment of Northern Rocky Mountain River Floodplains. These protocols are designed for, and will generally be used within, the context of the CWA Section 404 permit review process. However, they may also be used for other wetland management goals or objectives that require independent assessment of ecological functions (e.g., inventory, monitoring, ecosystem functional criteria).

This guidebook is designed to assess river floodplains on alluvial gravel-bed rivers in the northern Rocky Mountains. These river floodplains are a mosaic of intermittently flooded low riparian terraces and groundwater driven springbrooks, seeps, scour pools, ponds, and backwaters. No specific distinction is made in this assessment procedure between jurisdictional and nonjurisdictional wetlands. The focus of this procedure is on ecological function, not specifics of wetland regulations or delineation. It is critical to the success of each assessment that the Guidebook user be fully aware that the ecological function of the floodplain occurs as an integrated unit and that jurisdictional wetlands are embedded into and throughout the floodplain. Thus, to appropriately assess ecosystem function, the floodplain must be evaluated as a whole, not as individual wetlands. Likewise, to mitigate for wetland losses, both lentic and lotic wetland types must be replaced within a similar floodplain ecosystem context, further reinforcing the requirement of floodplain assessment rather than wetland-by-wetland assessment.

The typical application of this guidebook involves the examination of pre-project conditions and future-casting of one or more postproject scenarios, although application may also include back-casting to an earlier condition. To determine project impacts, the functional capacity of the floodplain is assessed under current preproject conditions and compared to the functional capacity under proposed postproject conditions. Data for the preproject assessment is normally collected under existing conditions, while data for the postproject assessment are normally based on predicted conditions. These assessment

protocols are organized to guide the Guidebook user through the steps necessary to conduct a hydrogeomorphic functional assessment of river floodplains and their associated wetlands on alluvial gravel-bed rivers in the northern Rocky Mountains. These protocols include:

a. Preliminary Tasks and Assembly of Pre-existing Data

(1) Statement of Purpose

(2) Initial Site Characterization and Collation of Pre-Existing Data

(3) Screen for Red Flags

b. Defining the Assessment Areas and Collection of Data

(1) Defining the Landscape Assessment Area (LAA)

(2) Defining the Wetland Assessment Area (WAA)

(3) Collection of Data at the Landscape Assessment Area Spatial Scale

(4) Collection of Data at the Wetland Assessment Area Spatial Scale

c. Data Entry and Analysis

(1) Data Entry

(2) Data Analysis

(3) Applying the Results of the Assessment

Preliminary Tasks and Assembly of Pre-Existing Data

Statement of purpose

The assessment process is begun with an unambiguous statement of the purpose of the assessment. This statement will often be as simple as, "The purpose of conducting this assessment is to determine how the proposed project will impact floodplain functions." Other potential objectives could be: (a) a comparison of several floodplains as part of alternatives analysis, (b) minimization of project impacts, (c) documentation of baseline conditions of the Landscape Assessment Area and the Project Wetland Assessment Area, (d) determination of mitigation requirements, (e) determination of mitigation success, or (f) determination of the effects of a specific management technique. A clear statement of the objectives will facilitate communication between the people conducting the assessment and will help to establish the approach taken in conducting the assessment. Of course, the specific approaches for applications will vary depending on whether the project is a Section 404 permit review, an Advanced Identification (ADID), or a Special Area Management Plan (SAMP) or has some other purpose altogether.

Initial site characterization and collation of pre-existing data

Site characterization involves describing the project area in terms of climate, landform and geomorphic setting, hydrology, vegetation, soils, land use, groundwater features, geology, urban areas, potential impacts, and any other relevant characteristics. It is essential to the completion of this assessment to have aerial photographs of the floodplain. Several of the variables operate at the landscape spatial scale, which can only be fully evaluated by observing the landscape through aerial photographs. It is preferable to have 1:6000 or 1:12000 photo series; however, 1:24000 may suffice under some circumstances. The characterization should also employ use of USGS 7.5-minute topographic quadrangle maps or a suitable alternative that shows the surrounding scale topography, roads, ditches, buildings, streams, rivers, etc. to assist in the photo interpretations. This information is essential to effectively provide a pre-characterization of the floodplain and to efficiently complete an assessment. The following does not preclude use of other materials or information sources, but rather is a short list of the minimum source materials needed to characterize a site and complete the assessment.

a. Aerial photographs (National Aerial Photography Program (NAPP), National High Altitude Photography (NHAP), US Forest Service, or digital Ortho-photographs covering the floodplain and the surrounding landscape

b. Topographic maps (1:24000 and 1:100000 scale) covering the floodplain and the surrounding landscape (e.g., USGS Quadrangle maps)

c. National Wetland Inventory maps (1:24000 and 1:100000 scale) covering the floodplain and the surrounding landscape

d. Climatic records are available for the western United States over the internet.
Go to: http://www.wrcc.dri.edu/climsum.html

e. Hydrologic records are available by state over the internet.
For Montana go to: http://mt.water.usgs.gov/
For Idaho go to: http://id.water.usgs.gov/
For Wyoming go to: http://wy.water.usgs.gov/

f. Soil survey maps

Following the initial steps in Site Characterization, an immediate check should be made for Red Flag conditions or features that may be inherent to the Reference Domain.

Screen for red flags

Red flags are special features that deserve recognition or protection that has been previously assigned. Screening for red flag features does not replace the execution of a functional assessment; however, if the assessment is being done

within the context of a 404 permit review, identification of a red flag (e.g., an Endangered Species Act (ESA) listed endangered plant or animal) may preclude approval of a permit. In other words, if a red flag condition or feature appears in a WAA, a functional assessment may not be necessary since consideration of that condition or feature may be so important that it becomes an overwhelming issue in consideration of the specific project and wetland impacts. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may be unnecessary within the 404 permit review, since the project may be denied or modified strictly on the basis of impacts to that species or habitat. Of course, this does not preclude conducting a functional assessment nor directly affect the outcome of Functional Capacity calculations.

Defining the Assessment Areas and Collection of Data

Defining the Landscape Assessment Area

Upstream and downstream confining reaches bound most river floodplains within the Reference Domain of the northern Rocky Mountains. This has a dramatic effect upon the function of the floodplain and the wetlands distributed across the floodplain surface. Wetlands located at the upper end of the floodplain function differently than wetlands developed under similar fluvial processes but located at the lower end of the floodplain. Furthermore, the wetlands within a particular project do not function independently of either the river or the other wetlands on the floodplain. It is therefore necessary to place the floodplain area being assessed into an appropriate ecological context. This can only be done by assessment of the floodplain both inside and outside of a typical project area. Several variables reflect human impact on the floodplain at a broad landscape scale; thus, necessitating evaluation across a "Landscape Assessment Area (LAA)."

The LAA must be selected carefully. Its size and position on the floodplain depend upon the ecological context of the specific floodplain that contains the project or any area that requires functional assessment. The LAA, as the name implies, is of sufficient size to encompass features that are essential to the functioning of the floodplain, but manifests at a spatial scale that usually is much larger than a specific project. The only time that this would not be the case is when a project is very large, thus covering a significant portion of the floodplain, both laterally and longitudinally. The location of the project and the individual characteristics of the floodplain determine the size and position of the LAA. Therefore there are no "hard-and-fast" rules, but only guidelines that can assist in making appropriate decisions. Typically, the LAA should occupy an area that extends across the width of the contemporary (i.e., Holocene) floodplain and is 2-7 times longer (i.e., upstream-downstream) than it is wide. Actual length is variable between floodplains, but should be sufficient to collect data and apply Variable Subindex Scores on those variables that are evaluated at this level. Figure 40 illustrates the size of the LAA for two different floodplains taken from the reference floodplain data set.

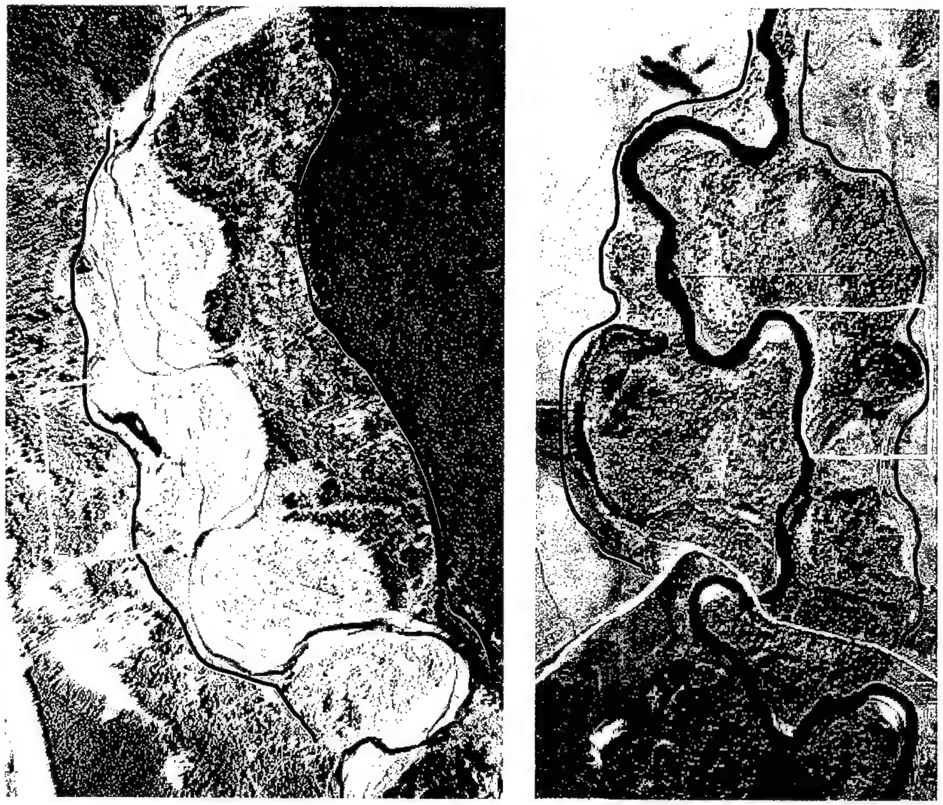


Figure 40. Two floodplains illustrating the appropriate size of the LAA (which extends between the red lines) and its position relative to the size and position of a proposed project requiring functional assessment (here marked by the yellow lines)

Defining the Wetland Assessment Area

The area of a proposed project circumscribes the Wetland Assessment Area (WAA). The term "WAA" is used in keeping with its extensive use among other HGM Guidebooks. However, it is critical to constantly keep in the forefront of the assessment that this Guidebook leads to floodplain functional assessment, not wetland assessment per se. Thus, it may also be useful to think of the WAA as a Project Assessment Area. Recall that the purpose of this guidebook is to assist in evaluation of whether the wetlands, with all their diversity in form and function, are functioning properly within the context of the floodplain complex. One of the first tasks in the specific protocols, described in detail below, is to identify different floodplain features with distinctly different deposits of alluvium, different elevations, different vegetation, and different lotic and lentic habitats that can be viewed from aerial photos and separated into cover types. Within the WAA, each cover type can be thought of as a separate Partial Wetland Assessment Area (PWAA) in which the Variable Subindex Scores that are evaluated at the WAA spatial scale are proportional to the area occupied by the specific cover type.

Collection of data at the Landscape Assessment Area spatial scale

Proportionality of Landscape Features ($V_{COMPLEX}$). This variable describes the distribution and relative abundance of common cover types that are readily discernible among the majority of alluvial gravel-bed river floodplains in the northern Rocky Mountains. $V_{COMPLEX}$ is an integral part of the description of landscape quality and the setting of the floodplain wetlands.

In evaluating and scaling this variable, a combination of the landscape resources acquired during the assembly of pre-existing data (e.g., aerial photographs, USGS quadrangle maps, National Wetlands Inventory maps) may be used to initially define the LAA. Within the LAA, the most recent aerial photographs available to differentiate between cover types (Table 26) should be used as a guide to cover type identification. These cover types correspond to the most frequently occurring cover types of vegetation and prominent fluvial features across the floodplain complexes found in the Reference Domain. If GIS capabilities (e.g., ArcInfo, ArcView, Grass) are available, cover typing can be easily accomplished by scanning the aerial photos and digitizing each cover type on a "heads-up" display of the floodplain (Figure 41). It may be necessary to "stitch" together stereo-pairs of photos to obtain a sufficiently large portion of the floodplain to determine project position as well as to adhere to the guidelines given above for determining the size of the LAA. If GIS capabilities are not available, then other techniques may be used, such as putting the photo interpretation directly on clear acetate overlaying the photos. To obtain areas of the different cover types when GIS is not available, one may use grid graph paper or count the frequency of dots on acetate placed over the delineated areas of the cover type map. Regardless of the technique used, the area of each cover type within the LAA must be calculated. The LAA boundaries and cover type mapping should be confirmed during the site visit. Adjustments may be made, as needed, by "ground truthing" the data.

Across the variation in human disturbance on floodplains in the Reference Domain, it is virtually impossible to account for all possible combinations of impact on the various cover types that affect the floodplain complex. Nonetheless, Table 27 presents a series of Variable Subindex Scores and various ranges of cover types as they commonly occur under different levels of common impact. It is at the discretion of the assessor using this Guidebook to use Table 27 as a guideline and make appropriate adjustments as needed. The Reference Standard (1.0) floodplain complex contains a mix of mature forest, immature cottonwood and willow stands, cottonwood seedling stands, open-canopy herbaceous cover, side- and back-channels, and cobble riverbed exposed during base flow. The Reference Standard contains no agricultural fields, no domestic or commercial buildings, no transportation corridors, and no modifications to the riverbed or banks (e.g., riprap, levees, dikes).

Floodplain Habitat Connectivity (V_{HABCON}). This variable describes the connectivity of forested floodplain habitats between and among surface wetland features and between the floodplain and surrounding upland areas. Connectivity of aquatic habitats between the channel and the floodplain are essential for the

Table 26
Cover Types Prevalent Among the Floodplain-Wetland Complexes of Alluvial Gravel-Bed Rivers of the Northern Rocky Mountains

Cover Type	Description
1	Mature conifer dominating the canopy, with interspersed mature cottonwood. Soils generally developing an A-horizon.
2	Mature cottonwood dominated (> 6-m height and >10 cm dbh), may have early stages of conifers that have not reached the forest canopy or may be entirely devoid of conifers.
3	Immature pole cottonwood 2-6 m in height and <10 cm dbh. May also have interspersion of willow. Soils are generally cobble dominated with fine sediments accumulating over the surface.
4	Cottonwood or willow seedlings and early seral stages up to 2 m in height. Substrate often with exposed cobble, but may also include deposited fines from flooding. Generally, soils are unstained by organics, indicating very early soil development.
5	Filled or partially filled abandoned channel dominated by mix of willows, alder, shrubs, and interspersed herbaceous cover. Also, often the dominant cover type along edge of backwaters. Soils are generally composed of deeper fines (>10 cm) with a developing A-horizon.
6	Herbaceous vegetation dominated, but may have interspersion of an occasional shrub (<10% of cover). This cover type is often associated with a filled side channel or abandoned back channel, but may be on any surface type.
7	Exposed cobble riverbed during base flow and inundated during most annual high flows. May have very sparse herbaceous vegetation or an occasional cottonwood or willow seedling composing <10% cover.
8	Main-channel surface during base flow, may be in a single tread channel or may be braided w/ islands.
9	Off main channel, water at the surface during base flow; includes springbrooks, oxbows, scour depressions and ponds, non-flow-through downstream connected side channels, and disconnected side channels.
10	Agricultural field, may be a meadow or plowed, often planted and hayed, may have origin as a forested surface, but now logged, or may have been a natural meadow.
11	Domestic or commercially developed land including homes, buildings, gravel pits, transportation corridors, etc.

movement of fish into off-channel habitats that are important for spawning, use as nursery grounds for immature life stages, and as refugia during flood. Connectivity between habitats used by birds and mammals are also essential to the safe movement of highly mobile animals that use floodplains during various portions of their life cycles (e.g., nesting, calving, foraging, etc.). Not only is it important to maintain connectivity, but it is also essential to maintain sites that are not connected. Many amphibians that use floodplain wetlands for spawning require a fishless environment for immature stages that are otherwise highly vulnerable to predation.

This is an important landscape scale variable that describes the interrelationship among the various floodplain habitats, including intermittently flooded terraces on the floodplain. In the Reference Standard condition, mixed conifer and cottonwood forests occupy over 50 percent of the intermittently flooded terraces. Human disturbance frequently reduces habitat connectivity by disconnecting movement corridors and significantly reducing forested habitats. Human disturbance also tends to result in reduction in aquatic/wetland habitat connectivity. Table 28 presents a series of approximate ranges of the various

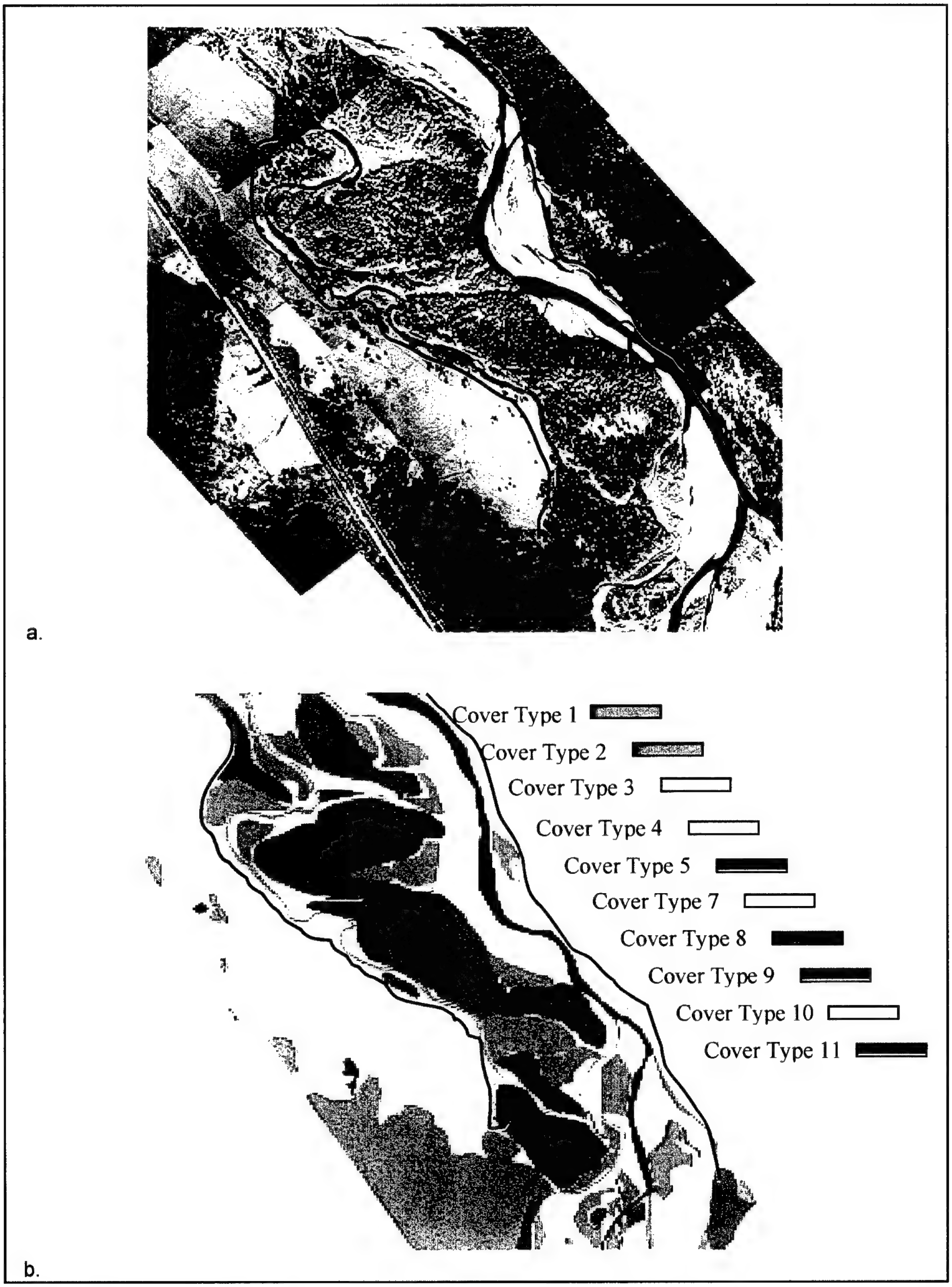


Figure 41. Composite aerial photograph of a floodplain showing the LAA within the red lines (a). Panel illustrates the appropriate level of detail of cover type mapping within the same LAA (b).

Table 27
Range of Percentages of Various Cover Types and the Respective Variable Subindex Scores that Reflect Variance from the Reference Standard Condition that has been Significantly Impacted with Loss of Floodplain Complexity

Cover Type	Variable Subindex Score								
	1.0	1.0	0.8	0.7	0.5	0.4	0.2	0.1	0.0
1	10-20%	0-10%	0-10%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%
2	20-40%	30-70%	>70%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
3	5-15%	5-10%	0-5%	0-5%	30-60%	0-10%	0-10%	0-10%	0-10%
4	5-15%	5-10%	0-5%	0-5%	20-50%	0-10%	0-10%	0-10%	0-10%
5	5-15%	5-10%	0-5%	0-5%	15-30%	5-15%	0-10%	0-10%	0-10%
6	10-30%	10-30%	0-10%	0-10%	15-30%	>60%	5-40%	5-40%	0-10%
7	5-20%	5-10%	<10%	<10%	<10%	<10%	<10%	<10%	0-10%
8	5-15%	5-15%	<10%	<10%	<15%	<15%	<15%	<15%	<10%
9	2-10%	2-10%	<10%	<10%	<10%	3-6%	3-6%	3-6%	<3%
10	0%	0%	<5%	<10%	10-20%	10-30%	10-30%	10-40%	10-40%
11	0%	0%	<2%	<5%	<5%	<5%	5-10%	10-30%	>40%

Table 28
Habitat Connectivity and Linear Linkages Between Riparian Habitats in the Form of Movement Corridors Between Cover Types as Well as Floodplain Lentic and Lotic Habitats and Corresponding Variable Subindex Scores

Description	Score
Cover Types 1-4 occupy 50 - 80% of area with well-developed connections between patches. Side channels, back and side channels, and floodplain scour pools and ponds well connected to main channel annually. Ponds not connected during base flow, thus permitting isolation for some species. No evidence of floodplain modification either increasing or decreasing connectivity.	1.0
Cover Types 1-4 occupy 25 - 50% of area with moderately well-developed connections between patches. Occasionally Cover Type 1-3 patches isolated. Side channels, paleochannels, and floodplain scour pools and ponds well connected to main channel 1 in 5 years. Either increased or decreased connectivity due to floodplain modification.	0.8
Cover Types 1-4 occupy 10- 25% of area with poorly developed connections between patches. At least 50% of Cover Type 1-3 patches isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds connected to main channel only in very high discharge years (1 in 25 to 50 years).	0.6
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds never connected to main channel.	0.4
Cover Types 1-4 occupy <10% of area with poorly developed connections between patches. Most remaining Cover Type 1-3 patches are small (<1 ha) and isolated. Side channels, abandoned floodplain channels, and floodplain scour pools and ponds are never connected and entering later stages of senescence.	0.2
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >25% of total area but less than 50%. Interconnectivity between floodplain wetlands and the main channel greatly reduced.	0.1
Cover Types 1-4 occupy <10%, replaced by Cover Types 10 and 11 >50% of total area. Interconnectivity between floodplain wetlands and the main channel absent.	0

cover types with losses of forested habitat interconnectivity and the extent of connectivity between the main river channel, side and back channels, spring-brooks, and floodplain ponds that commonly occur under different levels of impact.

In evaluating and scaling this variable, aerial photographs and onsite observation may be used to establish the level of impact and the appropriate Variable Subindex Score. Table 28 may be used as a guideline for scoring this variable at the LAA scale.

Geomorphic Modification (V_{GEOMOD}). This variable is best determined from a combination of observations from the aerial photographs and onsite evaluation. Frequently, this is an integral part of a proposed action or project that has led to the HGM functional assessment through a 404 permit process. It is the responsibility of the Guidebook user to evaluate specific past or future geomorphic modifications and the extent of their impact. Examples of geomorphic modification commonly practiced are riprap, revetment, dikes, levees, bridge approaches, and road-beds. These function to preclude the movement of water from the channel into off-channel wetlands (e.g., springbrooks, fluvial lentic-depressions, side channels). Geomorphic modification on floodplains has been done in the past to confine the river to protect roads from being eroded or to protect property for domestic, commercial, or agricultural purposes.

The modification to the wetland is geomorphic in nature, but the direct effect is on hydrologic properties of the floodplain and the long-term maintenance of the hydrologic regime, connectivity between the floodplain and the river, and the physical processes associated with cut-and-fill alluviation. This variable is calculated as a function of change on a per area basis and is linked to the relative percentage of the LAA that is affected by the modification. It is critical to the long-term ecological health of the floodplain and its river that the Guidebook user be familiar with the fact that the effects of geomorphic modification may extend far beyond the confines of a proposed WAA. Table 29 presents a series of approximate ranges of the various types and the extent of geomorphic modification that is common and an appropriate Variable Subindex Score that should be applied proportionally to the area of the LAA affected. This variable should be initially evaluated using the aerial photographs followed by field "ground truthing" that occurs while collecting the field data.

Macrotopographic Complexity (V_{MACRO}). This variable specifically describes the distribution and relative abundance of side channels, backwater channels, and abandoned channels and the connectivity between the main river channel and these floodplain features. Macrotopographic Complexity directly affects the flow of surface water onto and out of the floodplain, particularly in low flood years where water levels in the channel would not breach over floodplain terraces. This variable is integral to the description and characterization of landscape quality and the setting of the floodplain. Table 30 presents a series of approximate ranges of the various types and extent of Macrotopographic Complexity that is common and the appropriate Variable Subindex Scores that should be applied proportionally to the area of the LAA. This variable should be evaluated first using the aerial photographs followed by field "ground truthing" that occurs while collecting the field data.

Table 29
Calculation Table of Variable Subindex Scores Based on Unaltered and Altered Geomorphic Conditions on the Floodplain

Description	Score
No geomorphic modifications (e.g., dikes, levees, riprap, bridge approaches, road beds, etc.) made to contemporary (Holocene) floodplain surface.	1.0
Few changes to the floodplain surface with little impact on flooding. Changes restricted to < 1 m in elevation and only for farm roads or bridges with culverts maintained. Geomorphic modifications do however result in minor change in cut-and-fill alluviation.	0.75
Modification to the floodplain surface < 1 m in elevation. Riverbank with control structures (e.g., riprap) < 10% of river length along LAA. Geomorphic modifications result in measurable change in cut-and-fill alluviation.	0.5
Multiple geomorphic modifications to the floodplain surface to control flood energy, often with bank control structures, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in significant reduction in cut-and-fill alluviation.	0.25
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure or constructed to prevent channel avulsion, but still permitting flow access via culverts to backwater and side channels. Geomorphic modifications result in termination of cut-and-fill alluviation.	0.1
Complete geomorphic modification along the river channel of the floodplain surface to control flood energy. Bank control structures in the form of dikes and riprap in a continuous structure preventing channel avulsion and also preventing flow access via culverts to backwater and side channels	0

Table 30
Macrotopographic Complexity Across the Floodplain Surface Including Wetland Complexity and Linear Linkages of Wetlands and Other Aquatic Habitats and Corresponding Variable Subindex Scores

Description	Score
Multiple side and backwater channels and mix of old and new surfaces distributed across the floodplain. Floodplain channels frequently have active springbrooks.	1.0
Few side and backwater channels, with some evidence of active fluvial floodplain development. Floodplain channels rarely have active springbrooks.	0.8
Few old side and backwater channels, with no evidence of channel movement or fluvial floodplain development. Floodplain channels receive overbank flow annually, no active springbrooks.	0.6
A few very old side and backwater channels, with no new channels. Floodplain surfaces are generally old (>200 yrs). Floodplain channels receive overbank flooding occasionally (<10 yr cycle), no springbrooks.	0.4
Side and backwater channels few, obscure, and very old. Floodplain surfaces are generally old (>200 yrs). Floodplain channels only flooded during very highest floods, no springbrooks.	0.2
No side and backwater channels present on floodplain surface.	0.0

Frequency of Surface Flooding ($V_{SURFREQ}$). Among reference conditions of gravel-bed river floodplains in the northern Rocky Mountains, the normal frequency of recurrence for surface flooding of side channels, meander scrolls, abandoned channels, filled paleochannels, and fluvial depression wetlands is about 9 out of 10 years. Thus, based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals $\leq$1.3 years for these habitats. Figure 42 can be used to score the variable $V_{SURFREQ}$. Longer recurrence intervals are assigned a linearly decreasing subindex

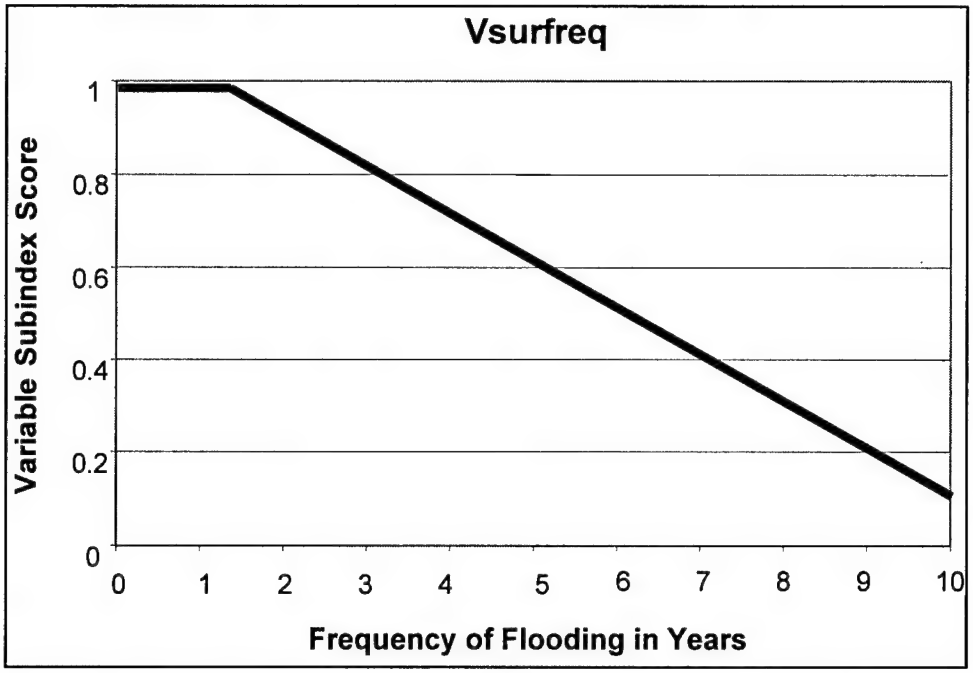


Figure 42. Relationship of surface flood recurrence and the corresponding Variable Subindex Score

to 0.1 at an interval of 10 years. If the floodplain floods at a frequency >10 years, then the score would be 0.1. If the floodplain side channels and paleochannels never flood because of hydrologic modification (e.g., upstream dam), then this variable should be scored as 0.0. This was based on the observation that entrenchment, channelization, dikes, and/or levees increase channel depth requiring a greater discharge to overtop the bank and inundate the floodplain and that various hydrologic modifiers, like dams, reduce flood levels and frequency.

In the Reference Standard condition, not only do connected side channels and paleochannels flood virtually every year, but floodplain surfaces that are often characterized by cottonwood forest or conifer-cottonwood mixed forest generally flood during more infrequent flood events. Very high-flow floods that inundate these higher floodplain surfaces occur approximately every decade. If there is direct evidence that the river hydrograph has been modified by flood control measures that affect the frequency of flooding across the entire contemporary floodplain, the score of this variable should be lowered an additional 0.1 for every additional decade of interval between major flooding. As an example, if a floodplain has been tentatively scored at 0.8, based on the flood frequency of side and paleochannels, but it is also determined that, due to an upstream dam, flood peaks have been curtailed and the floodplain areas dominated by forest vegetation flood about 1 year out of every 30 years, then the variable subindex score of 0.8 is lowered to a variable subindex score of 0.6.

Frequency of Subsurface Flooding ($V_{SUBFREQ}$). Among Reference Standard gravel-bed river floodplains in the northern Rocky Mountains, side channels, meander scrolls, and fluvial depressions are extensively connected via subsurface pathways of preferential flow. This variable is scaled at a frequency of subsurface flooding of each year at 1.0 and greater than 5 years at 0.1 (Figure 43). Floodplains may lose subsurface flooding if the river becomes incised or the river bottom becomes armored with fine sediments and entry points into the pathways of preferential flow are lost or sealed. If modification to the floodplain through construction of levees or dikes, degradation of the river bed, or modification to the hydrologic regime is sufficient to hydrologically disconnect the river from the floodplain via subsurface flooding (e.g., upstream high-head hydroelectric dam), one may conclude that subsurface flooding has been diminished or eliminated from the river. A combination of onsite indicators (e.g., flowing springbrooks, flooded ponds during late base flow), river hydrographic data, and local knowledge may be used to obtain a frequency of subsurface flooding.

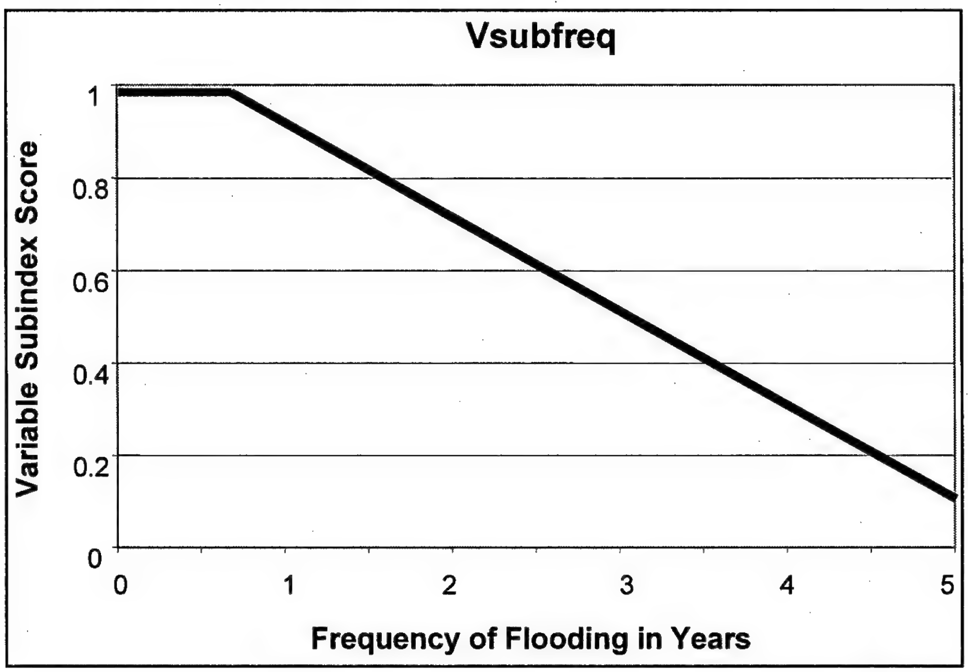


Figure 43. Relationship of subsurface flood recurrence and the corresponding Variable Subindex Score

Collection of data at the Wetland Assessment Area spatial scale

The calculation of the variables that are assessed at the Wetland Assessment Scale, that is within a particular project area, is based on scaling of each variable within each polygon delineated through the cover type mapping procedures completed earlier in the protocols. Variables are applied to the cover type polygons only as they are appropriate, and each variable is scored only within those cover types where it is appropriate to make an evaluation. For example, Cover Type 7 (i.e., cobble riverbed exposed during base flow) does not have trees, nor should it have trees in the Reference Standard condition. Thus, the

variable V_{DTREE} is not evaluated or scored for Cover Type 7, nor is it applied proportionally to the area occupied, in this example, by Cover Type 7.

At the WAA spatial scale, the Variable Subindex Scores are determined proportionally for each of the variables evaluated by cover type. Thus, the final Variable Subindex Score for the WAA for each variable is based on the proportional area covered by each evaluated cover type. This is illustrated in the following scenario. A WAA 100 acres in size has been cover typed and contains the following polygons:

Cover Type	Polygon	Area (acres)
2	1	20
5	2	25
2	3	30
8	4	4
9	5	2
7	6	3
3	7	1
4	8	5
10	9	10

In this scenario, the variable V_{DTREE} is being evaluated. Since only cover types 2 and 3 (Polygons 1, 3, and 7) are evaluated for V_{DTREE}, if Polygon 1 is scored at V_{DTREE} = 0.8; Polygon 3 is scored at V_{DTREE} = 0.5, and Polygon 7 is scored at V_{DTREE} = 1.0, then the Variable Subindex Score for the WAA for the variable V_{DTREE} is:

$$\left[\frac{(20\times 0.8)+(30\times 0.5)+(1.0\times 1)}{(20+30+1)}\right]=0.63$$

Both Cover Types 10 and 11 are handled differently than the other Cover Types. Cover Type 10 surfaces are agricultural fields that may be hayed or, rarely, plowed. However, they are also often fields that were once forested. Cover Type 10 requires the Guidebook user to determine the likely natural origin of the polygon based on the surrounding polygons and an understanding of floodplain habitats. If the Guidebook user determines that the Cover Type 10 in the above scenario was a cottonwood forest gallery prior to conversion to a hay field, then the Cover Type 2 regressions are used to provide a score for that polygon, in this case Polygon 9. This would change the calculations of V_{DTREE} for the WAA to the following if Polygon 9 was deforested and now had a score of 0:

$$\left[\frac{(20\times 0.8)+(30\times 0.5)+(1.0\times 1)+(0.0\times 10)}{(20+30+1+10)}\right]=0.52$$

Cover Type 11 also requires the Guidebook user to determine the likely natural origin of the polygon. However unlike Cover Type 10, Cover Type 11 always scores 0 for all variables that would be scored for the naturally occurring cover type. Both Cover Types 10 and 11 are scored and proportionalized by area within the WAA.

Proportional Landuse ($V_{LANDUSE}$). This variable is a function of the various land uses and their relative impact on the floodplain. The calculation of this variable is based on the general land use within each cover type in the WAA and thus must be evaluated onsite. Frequently a single land use will extend over an entire WAA. However, when land use changes from polygon to polygon or from one side of the WAA to the other, as may occur, for example, if a WAA is divided along a fence line or is affected by a road, then the different land uses are scored according to the area they occupy. Table 31 presents a series of commonly occurring land uses within the Reference Domain.

The Variable Subindex Score, as described in Table 31, is applied to each affected polygon within the WAA and applied proportionally to each polygon based on the summation of scores as described above.

Table 31
Calculation Table of Current Land Use and the Corresponding Variable Subindex Scores for Many of the Prevalent Land Uses Encountered on River Floodplains Across the Northern Rocky Mountains

Current Land Use	Score
Commercial right-of-way, with or without paving, road or parking lot	0.0
Domestic or commercially developed with buildings	0.0
Gravel pit operation	0.0
Unpaved, private right-of-way (e.g., driveway, tractor trail)	0.1
Tilled crop production	0.2
Heavy grazing by livestock	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Seasonally used for wintering livestock	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Wildlands or managed for native vegetation coverage and diversity	1.0

Decomposition of Organic Matter($V_{ORGDECOMP}$). This variable is an indicator of organic matter decomposition and, thus, the microbial decomposition side of nutrient cycling in the surface soils of the floodplain complex. This variable focuses on both the O-Horizon and the Surface Mineral Soil (SMS) Horizon, which may be either an A-Horizon in well-developed soils or an E-Horizon in poorly developed soils. $V_{ORGDECOMP}$ is evaluated in the field in Cover Types 1-6 only. Cover Types 7-9 are not included in the proportional calculations. Cover Type 10 is given an automatic score of 0.1 and included in the proportional calculation of the Variable Subindex Score for the WAA. Cover Type 11 is given an automatic score of 0.0 and is included in the proportional calculation of the Variable Subindex Score for the WAA.

A soil pit must be dug in each polygon representing Cover Types 1-6. Pits must be deep enough to obtain the data of the thickness of the O-Horizon (cm), the thickness of the SMS-Horizon (cm), and the Soil Color Value (from Munsell Soil Color Chart) of the SMS-Horizon.

These data are used to calculate an Organic Matter Decomposition Factor (OMDF) for each polygon. The OMDF is calculated as:

$$OMDF = \left[(OHorizonDepth) + \left(\frac{SMSHorizonDepth}{SoilColorValue} \right) \right]$$

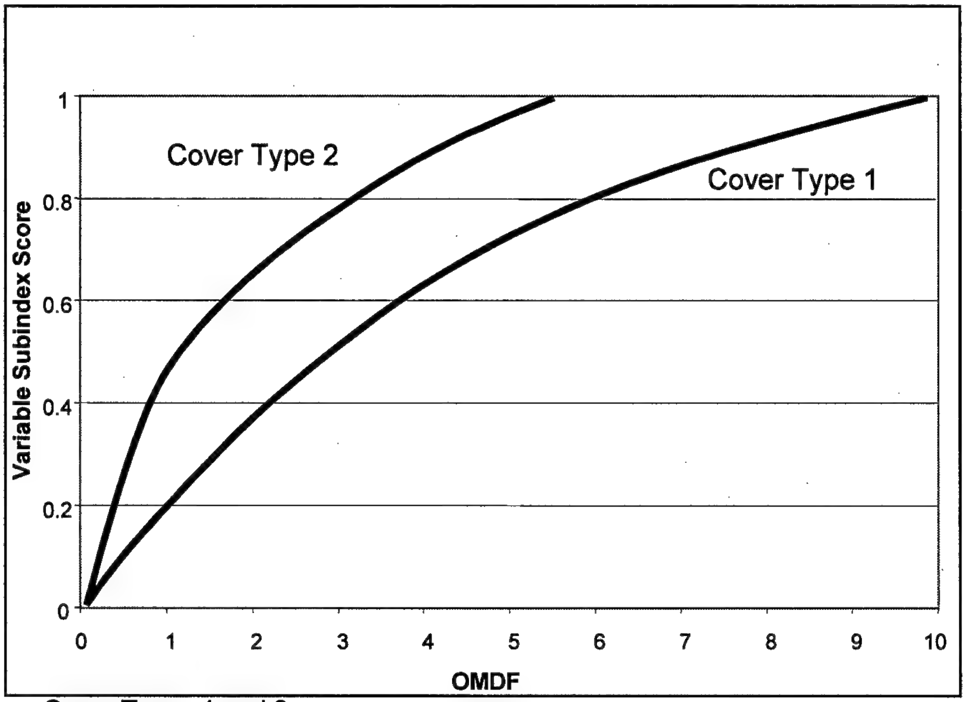
The depth and color of the SMS-Horizon is an index of the soil's organic matter accumulations. Both the A-Horizon and E-Horizon are characterized, to varying degrees, by the accumulation of humus within the mineral soil. Humus is black in color, highly decomposed, and naturally colloidal (i.e., has a small particle size, large surface area, and net negative charge). Its ability to hold nutrients is greater than any other soil constituent. Because the surfaces of these floodplains are relatively young (many <200 years), soils are often poorly developed; thus many of the mineral soils are present as an E-Horizon rather than the more developed A-Horizon common in uplands.

The depth and color of the SMS-Horizon is an index of the soil's ability to store nutrients for plant availability. Departures from reference standards are indicators of changes in long-term organic matter inputs. A thin, lightly colored SMS-Horizon may be the result of lowered productivity caused by some form of human disturbance or management.

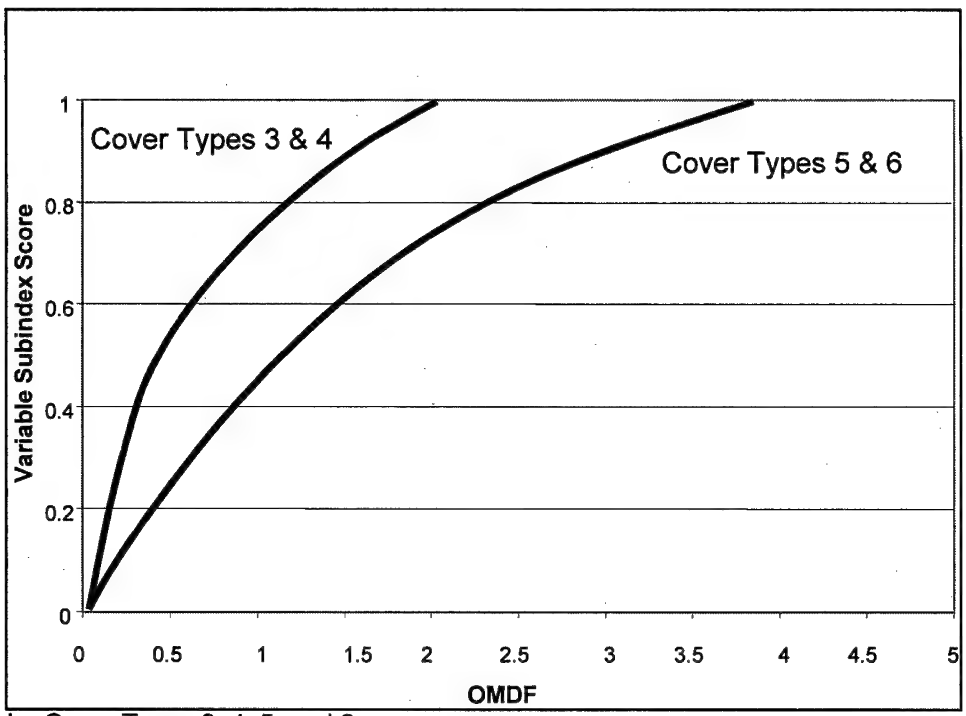
The Variable Subindex Score for the OMDF from each cover type polygon can be determined as illustrated in Figure 44a for Cover Types 1 and 2 soils and Figure 44b for Cover Types 3, 4, 5, and 6 soils. The final $V_{ORGDECOMP}$ Variable Subindex Score is determined proportionally to the area of each polygon.

Data used to calculate the variables V_{DTREE}, V_{SHRUB}, V_{HERB}, V_{LWD}, and V_{NPCOV} should be collected after all other field data have been collected, thus maximizing familiarity with the site prior to evaluating this segment of the assessment. The variable V_{LWD} is determined for Cover Type 7 only. Although large wood debris plays an important role on the floodplain other than within Cover Type 7, data show that this variable does not correlate well with the human impact gradient among the other cover types. Each polygon of Cover Types 1-6 identified and delineated in the GIS mapping of the aerial photographs should be used to refine decisions regarding vegetation sampling. Each plant community within the array of cover types must be characterized for community composition and coverage of native and non-native species within the project WAA. It is important to remember that the objective of the assessment is to characterize the floodplain, not to describe the extent of variation of vegetation within each of the various cover types. Therefore, when selecting locations for sampling, plot sites that represent the vegetation community being sampled should be selected.

Selection of polygons to be sampled varies between WAAs and depends on the diversity of cover types and WAA size. At a minimum, each Cover Types 1-6 represented in the WAA is sampled for the vegetation variables. When a cover type is distributed across several polygons, typically vegetation will need to be sampled in each polygon. However, the Guidebook user may determine from the aerial photographs and in-field observation that the same



a. Cover Types 1 and 2



b. Cover Types 3, 4, 5, and 6

Figure 44. Correlation between $V_{ORGDECOMP}$ OMDF and the Variable Subindex Score for Cover Types 1-6

cover type distributed across several polygons is sufficiently similar to justify concentrating sampling in 1 or 2 of the polygons and applying the results to the other polygons of the same cover type.

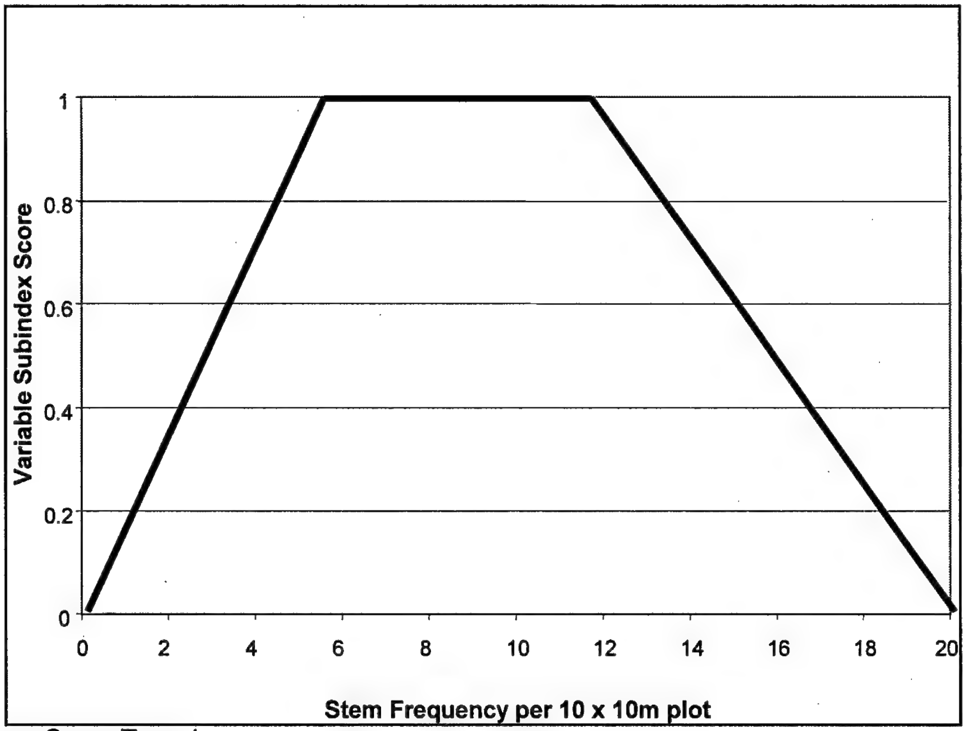
In forested cover types (Cover Types 1 and 2), mark out three 10-m by 10-m plots and count the number of tree stems or boles >10 cm dbh or >6-m height. If the density of trees is low or particularly patchy, increase the size or shape of the plot. However, all density regressions are based on the number of stems per 100 m^2. Mark out three 5-m by 5-m plots and identify all shrub species and estimate their percent coverage, by species. These 5-m by 5-m plots may be within the 10-m by 10-m "tree stem" plots. Within the selected 5-m by 5-m shrub plots, estimate the percent coverage of all herbaceous plant species that comprise a coverage exceeding 1 percent of the total coverage.

In pole cottonwood, willow and shrub dominated cover types (Cover Types 3, 4, and 5), mark out three 5-m by 5-m plots and identify all shrub species and estimate their percent coverage, by species. Within the selected 5-m by 5-m shrub plots, estimate the percent coverage of all herbaceous plant species that comprise a coverage exceeding 1 percent of the total coverage.

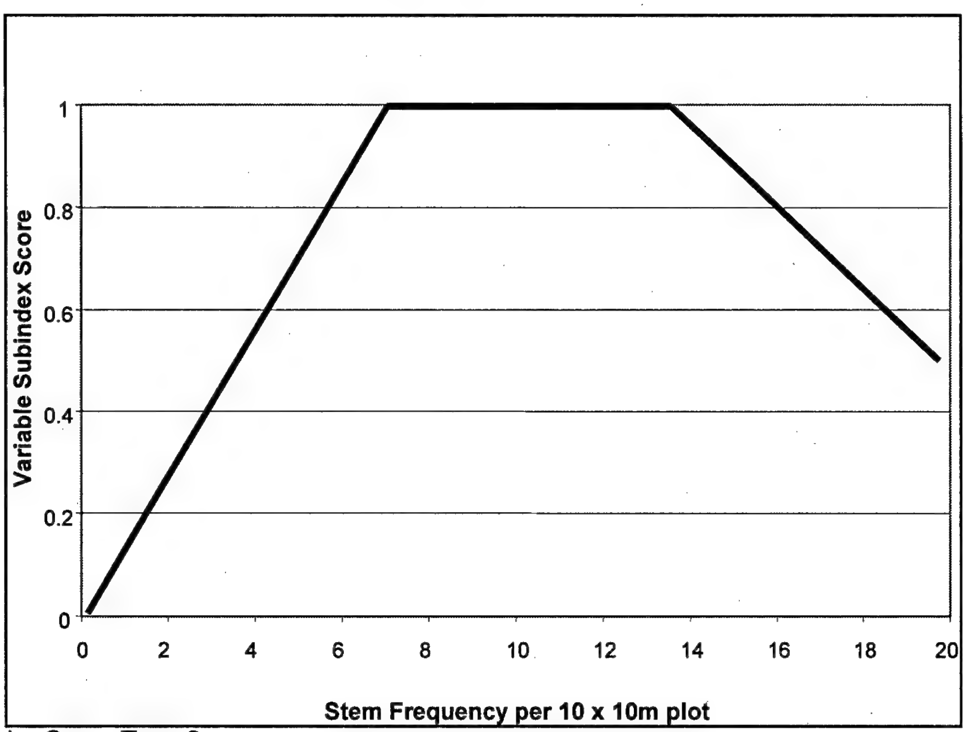
In the herbaceous dominated Cover Type (Cover Type 6) use three 1-m^2 plots and identify and estimate the percent coverages of herbaceous plant species that comprise a coverage exceeding 1 percent of the total. For species that occur in patches, mark out three 5-m by 5-m plots and identify all herbaceous species and estimate their percent coverage.

The Guidebook user must be sufficiently familiar with tree, shrub, and herbaceous vegetation to identify all the commonly occurring species and must be particularly familiar with non-native species so that they can be identified by sight recognition. After becoming familiar with the Guidebook field collection and data analysis, users will note that the variable V_{NPCOV} requires estimates of the percentage of native plant coverage, which can be determined without developing detailed species lists and relative coverages of every species. However, it does require a basic knowledge of plant taxonomy and the ability to recognize which plant species are native and which are non-native.

Tree Density (V_{DTREE}). This variable represents the number of trees per unit area across the forested Cover Types of the riparian floodplain. Trees are defined as woody stems >6 m in height and >10 cm dbh. In most forested systems, tree stem density and basal area increase rapidly during the early successional phases. This is also true in the northern Rocky Mountain floodplain systems. The density of tree stems per sample plot is used to quantify this variable. The number of tree stems in a 10- by 10-m plot are counted. The number of sample plots required to adequately characterize the area being assessed will depend on the polygon size and heterogeneity of the forest within the polygon. At least three plots in any one stand or floodplain polygon should be sampled, more if heterogeneity is high, then the results from all plots are averaged. The Variable Subindex Score for V_{DTREE} in Cover Type 1 is determined as illustrated in Figure 45a, as is Cover Type 2 in Figure 45b.



a. Cover Type 1

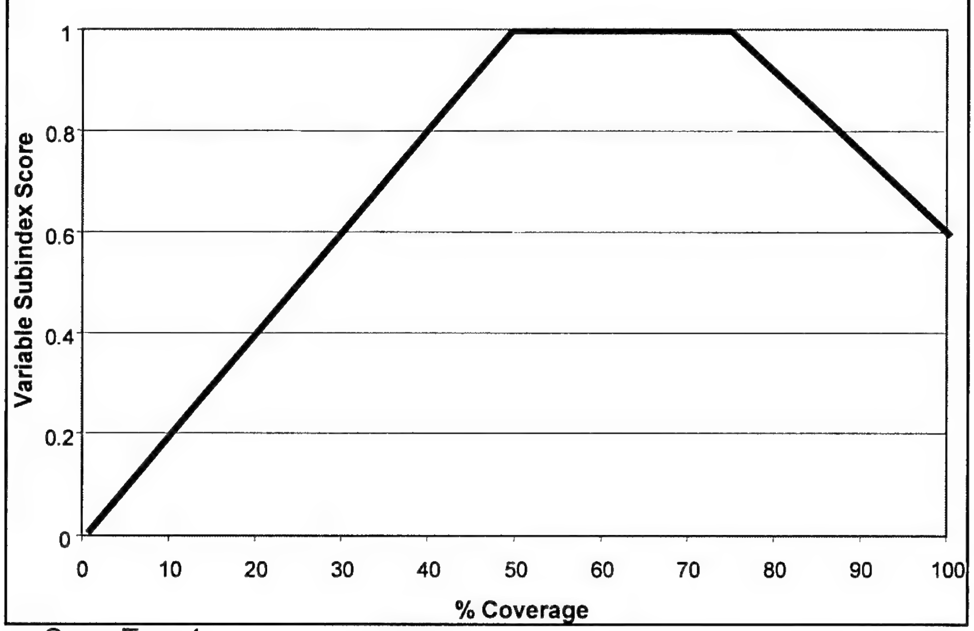


b. Cover Type 2

Figure 45. Tree stem density and corresponding Variable Subindex Scores for Cover Types 1 and 2

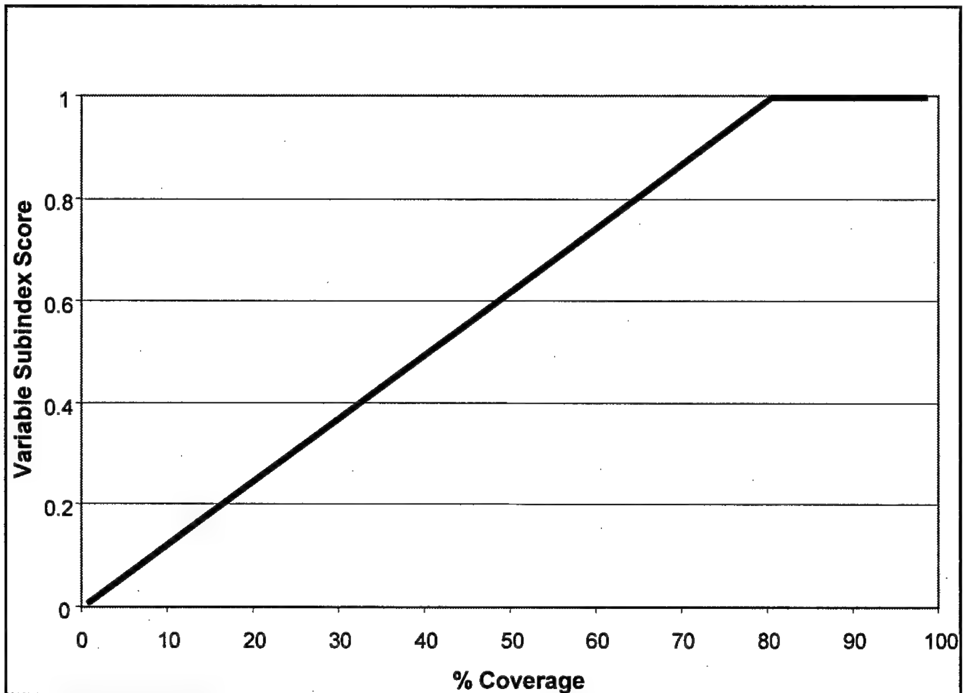
Pole Cottonwood, Willow, Shrub, and Sapling Coverage (V_{SHRUB}). This variable represents the percent coverage of the shrub, willow, and pole cottonwood dominated stands in Cover Types 3-5 and the shrub layer under the forested canopy in Cover Types 1 and 2. Shrubs and saplings are defined as woody stems <6 m in height and <10 cm dbh. In Cover Types 1 and 2, the shrub and sapling layer tends to be very diverse. Density of coverage is highly variable among Reference Standard sites, yet is responsive to human disturbance from either grazing, which decreases coverage or from other impacts that decrease coverage. The Variable Subindex Score for V_{SHRUB} in Cover Type 1 is determined as illustrated in Figure 46a, as is Cover Type 2 in Figure 46b.

The Cover Type 3 surfaces are dominated by pole cottonwoods 3-10 cm in dbh and 2-6 m in height with occasional clumps of young willows. This Cover Type emerges out of relatively young surfaces that have been exposed following large floods and colonization by cottonwood seedlings that have matured into pole stands. Cover Type 3 stands are generally 10-25 yrs depending on growth rates. The Variable Subindex Score for V_{SHRUB} in Cover Type 3 can be determined as illustrated in Figure 46c.

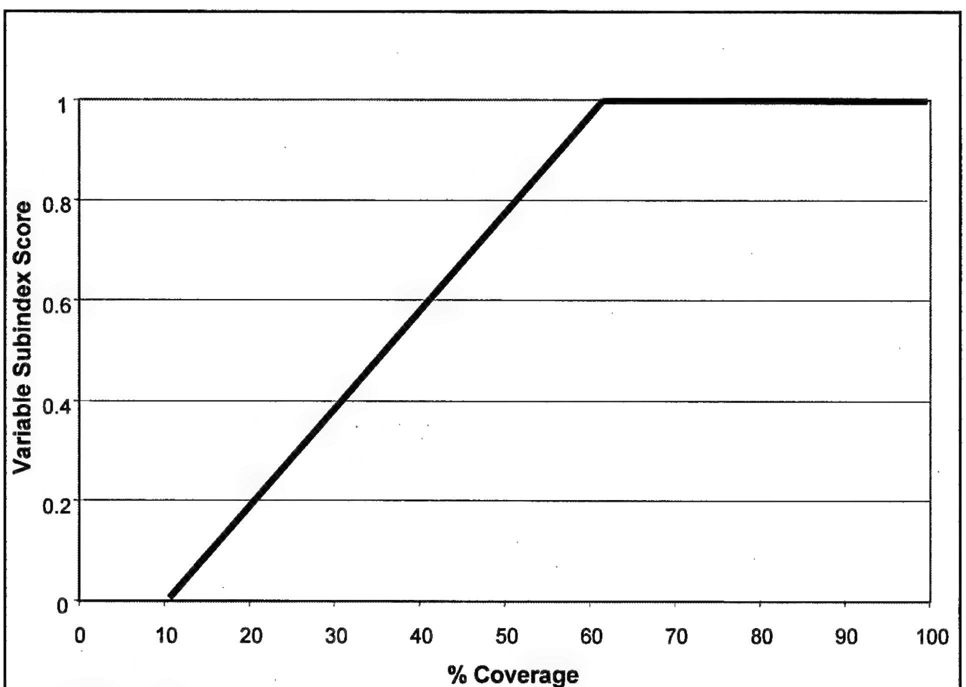


a. Cover Type 1

Figure 46. Percent coverage of the shrub layer of plants and corresponding Variable Subindex Scores for Cover Types 1-5 (Sheet 1 of 3)

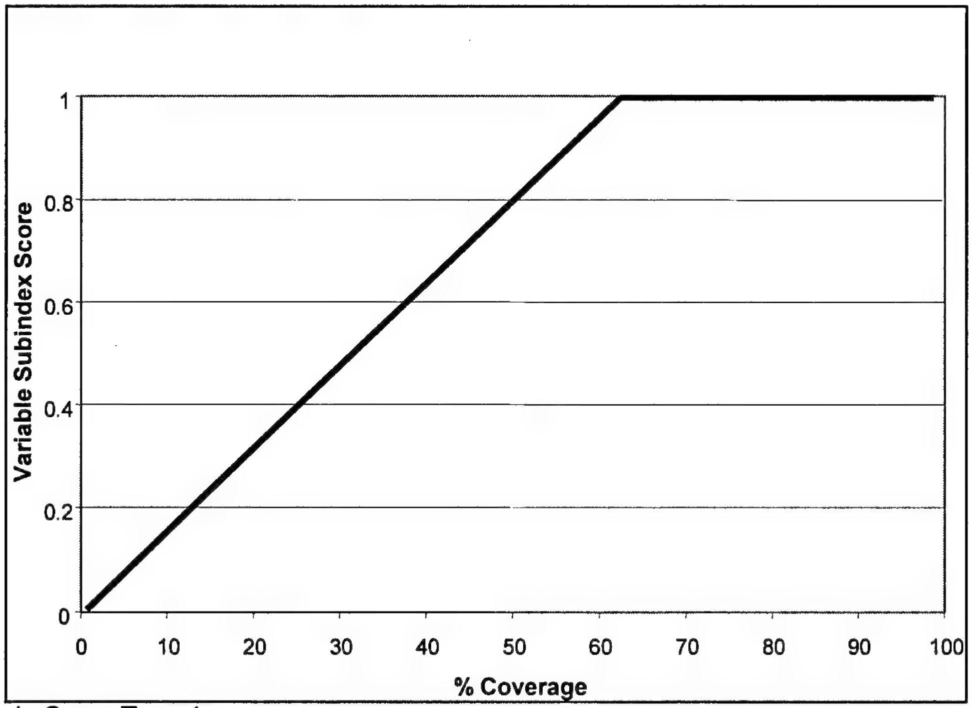


b. Cover Type 2

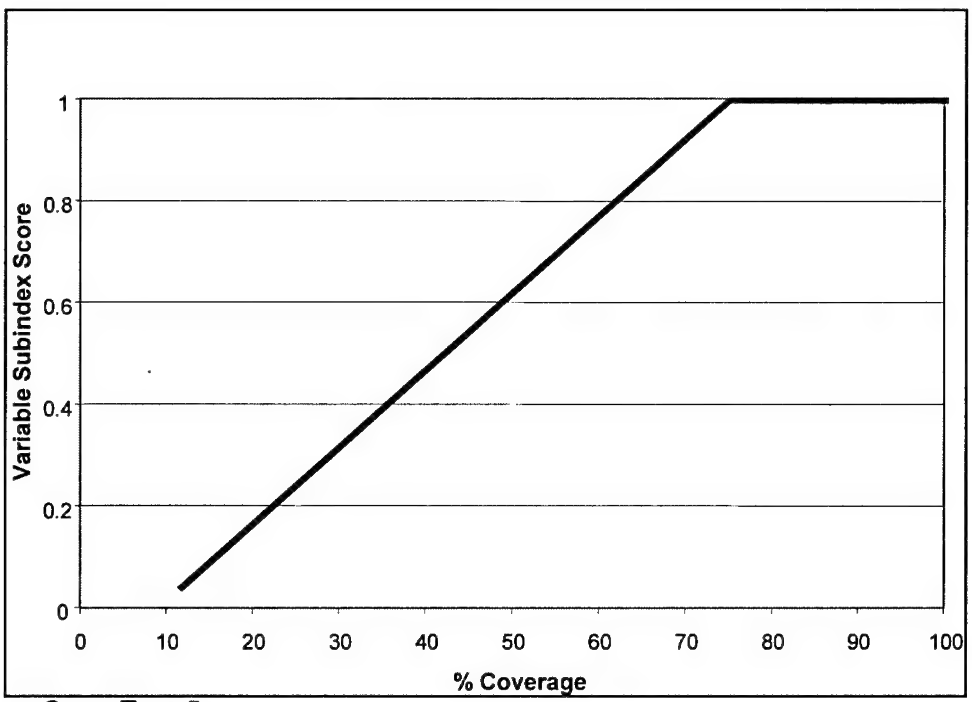


c. Cover Type 3

Figure 46. (Sheet 2 of 3)



d. Cover Type 4



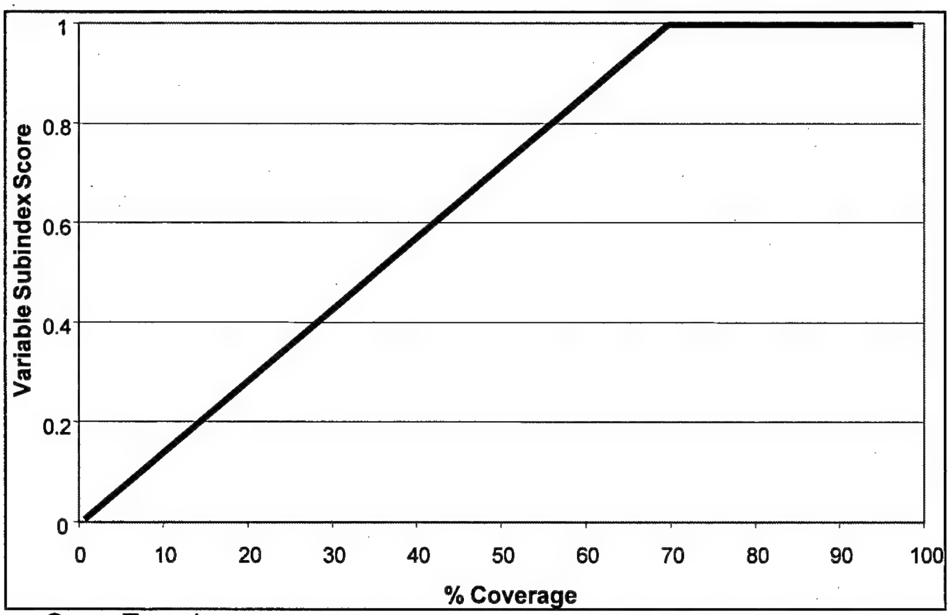
e. Cover Type 5

Figure 46. (Sheet 3 of 3)

The Cover Type 4 surfaces are dominated by cottonwood seedlings and young willow stands that are in early successional stages, generally following colonization of gravel bars following large floods and that then lead to Cover Type 3 surfaces. These habitats are often characterized by cobble near the surface with fine textured sediments deposited between the cobbles. The Variable Subindex Score for V_{SHRUB} in Cover Type 4 can be determined as illustrated in Figure 46d.

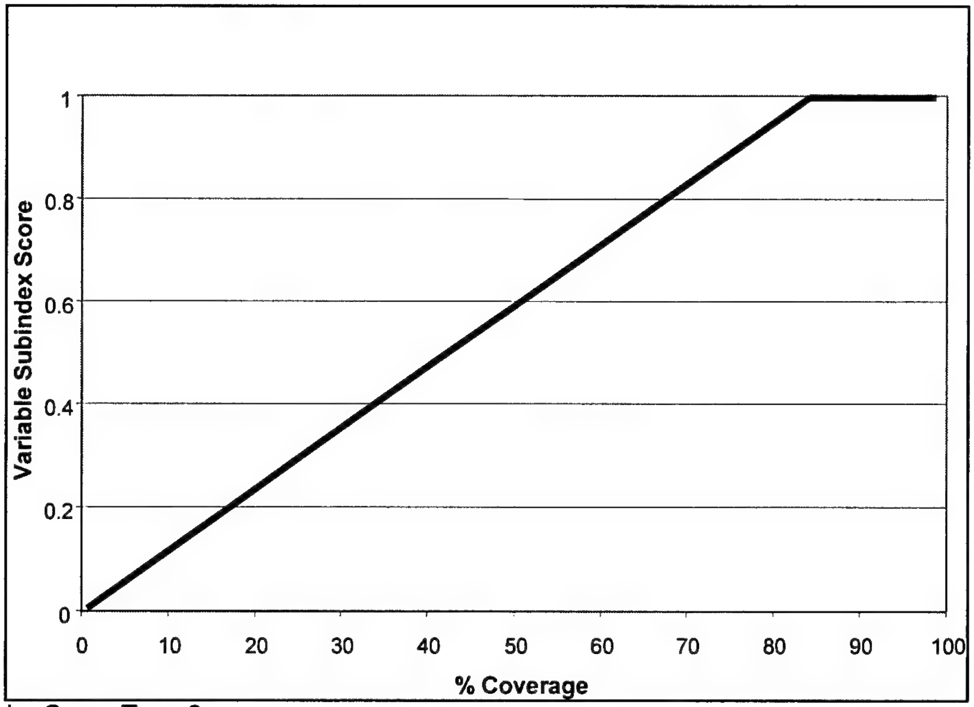
In Cover Type 5, shrub layer is dominated by willows and occasionally alder. This cover type is generally found along the edges of backwater and side channels or on the surface of filled paleochannels. This cover type has much older vegetation than either Cover Types 3 or 4. Willows in Cover Type 5 may occur in large, very mature clumps. Cover Type 5 is also often surrounded by Cover Types 1 and 2, but, due to extremely wet soils that have groundwater near the surface even at base flow, these areas are dominated by hydrophilic shrubs. The Variable Subindex Score for V_{SHRUB} in Cover Type 5 can be determined as illustrated in Figure 46e.

Herbaceous Plant Coverage (V_{HERB}). This variable represents the percent coverage of herbaceous plants per unit area from Cover Types 1-6. The herbaceous layer is defined as all herbaceous grasses and forbes. The herbaceous coverage is particularly sensitive to the extent of human disturbance on the floodplain. Herb coverage is measured generally within a 1-m by 1-m plot, but users may increase the size of plots as needed to appropriately describe this variable. It is common to encounter narrow polygons of Cover Type 6, which is the only cover type containing herbs and forbes only. Figure 47 presents the density of herbs expressed as percent coverage and the corresponding Variable Subindex Scores for each of the six cover types that are evaluated for this variable.

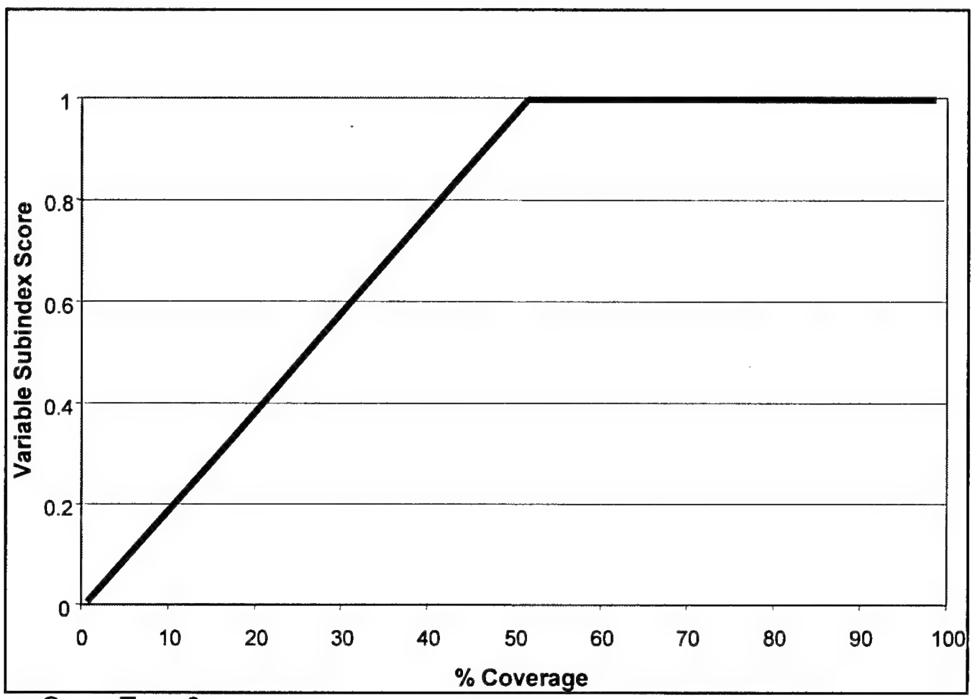


a. Cover Type 1

Figure 47. Percent coverage of the herbaceous layer of plants and corresponding Variable Subindex Scores for Cover Types 1-6 (Sheet 1 of 4)

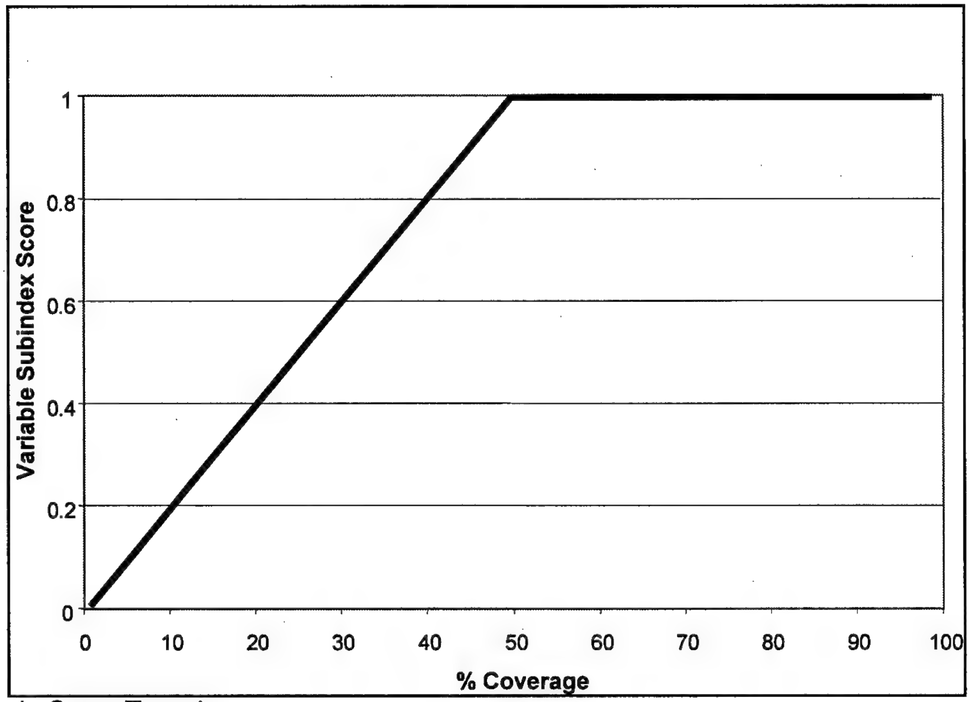


b. Cover Type 2

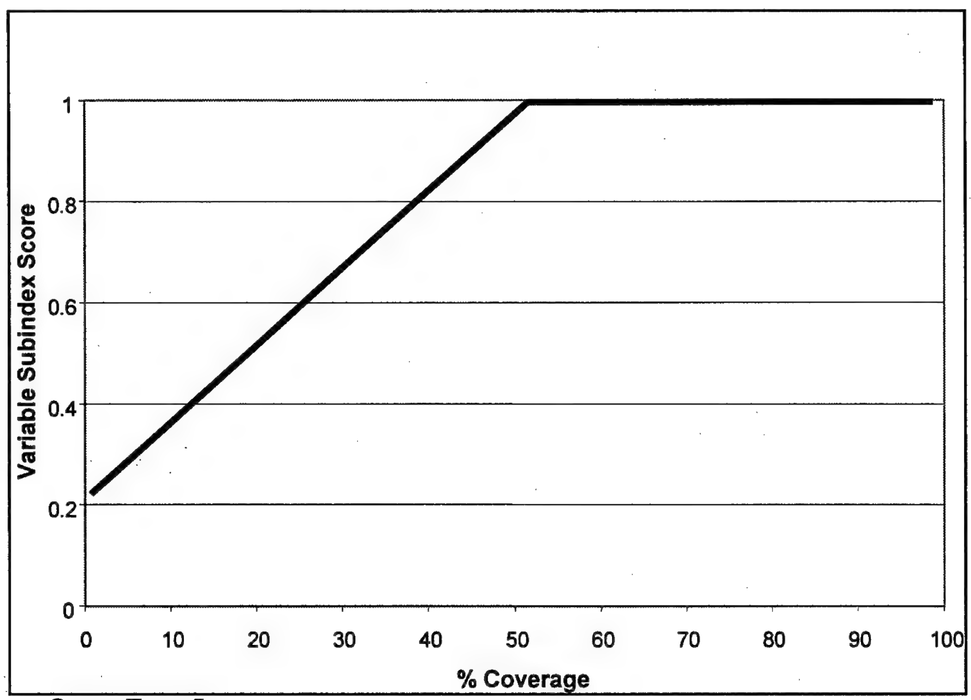


c. Cover Type 3

Figure 47. (Sheet 2 of 4)

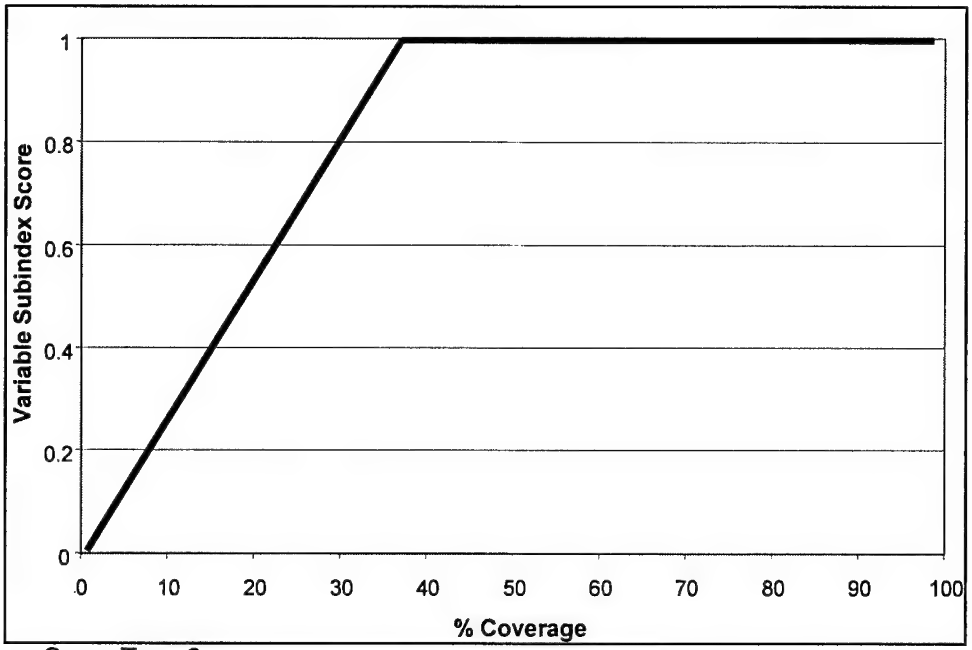


d. Cover Type 4



e. Cover Type 5

Figure 47. (Sheet 3 of 4)



e. Cover Type 6

Figure 47. (Sheet 4 of 4)

Large Wood Debris (V_{LWD}). Large Wood Debris (LWD) for this assessment procedure is defined as wood >10 cm in diameter and >6 m in length. LDW is measured in Cover Type 7 only and is quantified by measuring the frequency of LWD pieces along a 10-m by 50-m transect. Frequency is quantified as a simple numeric count. At least three transects should be to sampled. The transects should be selected as representative of what is observed distributed across the Cover Type 7 polygon being sampled. Again, the purpose is to characterize the variable, not describe variation. All LWD pieces that meet the size requirement and have at least 2 m of bole length within the transect being sampled should be counted. It is not unusual to find LWD pieces with the majority of their length outside the transect. Nonetheless, the piece is counted if it meets the size requirement and 2 m or more of the length are within the transect. The Variable Subindex Score for V_{LWD} in Cover Type 7 is determined as illustrated in Figure 48.

Percent Coverage by Native Plants (V_{NPCOV}). Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation), as well as animal populations, are adapted to native plants for food, cover, nesting, etc. Non-native plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance.

This variable represents the weighted mean percent coverage of native plants within each of Cover Types 1-6 by vegetation layer. The concept and calculation of this variable is a measure of the percent coverage by native plants. This variable is quantified by estimating the percent coverage within each polygon and vegetation layer that is contributed by native plants and determining the Variable Subindex Score (Figure 49). Thus, the score for each polygon is determined as

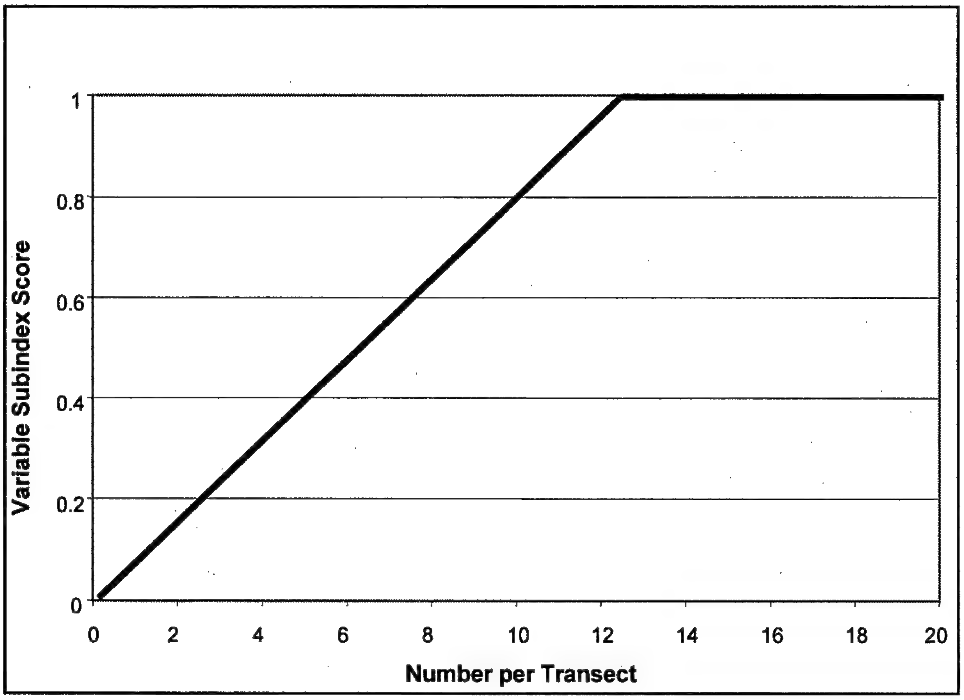


Figure 48. LWD frequency per transect and corresponding Variable Subindex Score

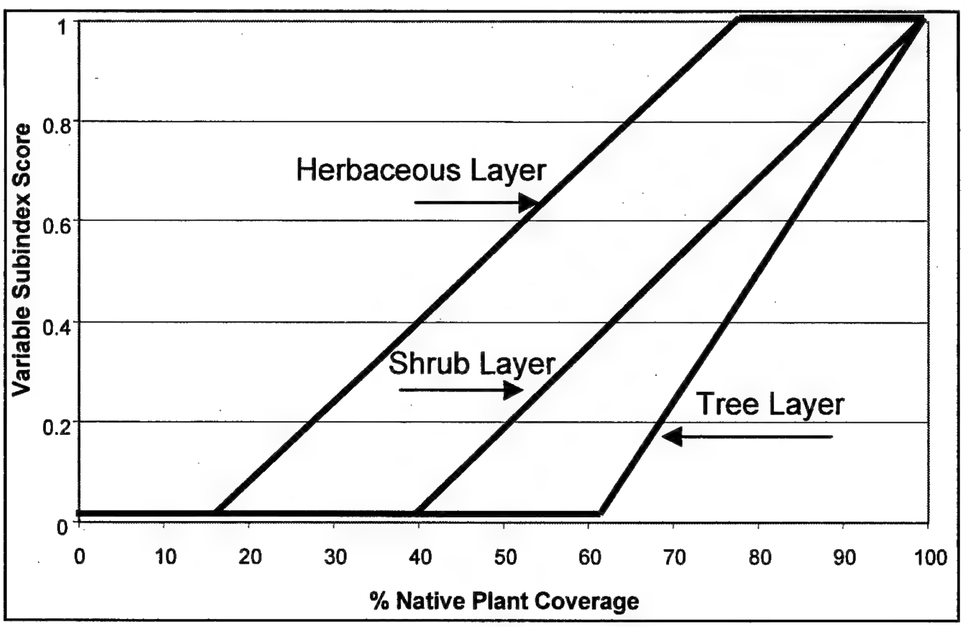


Figure 49. Correlation between percent native plant cover and corresponding Variable Subindex Scores by vegetation layer

the average score from each of the vegetation layers. For example, Cover Type 1 has three vegetation layers: trees, shrubs, and herbaceous plants. An average score should be obtained for each layer within the polygon. Different layers have different scores for the percent coverage of native plants. The average score should be determined for each polygon. The final Variable Subindex Score for the entire WAA is the average of the polygon scores weighted by area of each polygon.

Data Entry and Analysis

Data entry

Following the Assessment Protocols given above, the wetland functional assessment should be completed by ascertaining that all necessary data have been acquired. It is critical that all data entry is made on the various Data Collection Forms provided with this guidebook provided in Chapter 6. This will greatly reduce confusion about what data need to be collected and will help prevent accidentally skipping over necessary steps or getting steps out of sequence. Much of the initial site characterization and map data will come from pre-existing databases, internet library sources (e.g., USGS, NRIS), or office source materials (e.g., NWI maps, county soil survey maps). Collation of these materials and analysis of LAA spatial scale variables are generally done in the office and will require about half a day's work, plus any GIS time to cover type the floodplain. This can be done in about 1-2 hr, depending on the expertise of the user. Collection of field data for a single project WAA of moderate size (10-20 acres) and complexity (6-8 cover type polygons) will generally require one person one day, or two people half a day to complete. This may require more time initially, but experience with the assessment procedure will reduce the required time.

Data analysis

The primary objective of the HGM Approach to the Functional Assessment of Wetlands is the determination of Functional Capacity Indices which, when combined with area, produces a Functional Capacity Unit for each function. The Functional Capacity Unit, in turn, provides a basis for determination of impact and mitigation (Smith et al. 1998).

After collection of all data and completion of the data sheets, the Variable Subindex Scores for each variable must be calculated. For the LAA variables, this is accomplished directly from a single analysis for each variable done for the project assessment. For the WAA variables, each final Variable Subindex Score is calculated from the aggregation of weighted-mean scores from the array of cover type polygons in the WAA. Final Variable Subindex Scores for the LAA and WAA are then used to calculate a Functional Capacity Index for each function for the floodplain that is being assessed within the scope of the project. The FCI Worksheet is provided in Chapter 6 for a review of the FCI models.

Applying the results of the assessment

Once the assessment and analysis phases are complete, the results can be used to compare the same WAA at different times, compare different WAAs at the same time, compare different alternatives to a project, or compare different HGM classes or subclasses as per Smith et al. (1995) and Davis (1998b).

Users of this guidebook must keep in mind that HGM functional assessment is a tool to be used toward better understanding of ecosystem function. In the case of northern Rocky Mountain riverine wetlands, this is accomplished through a functional analysis of the floodplain, which contains both jurisdictional and nonjurisdictional wetlands.

Functional Capacity Indices provide specific metrics that may be used to calculate degree of functional impairment or functional improvement. HGM functional assessment can dramatically assist the river/wetland scientist for purposes of inventory, monitoring, and determining ecological health of a river floodplain and its associated wetlands. It can also assist wetland regulators in the implementation of policy. It will not, however, replace the fundamental decision- making processes necessary to establish sound management. It also requires an understanding of fundamental principles in river and wetland ecology and can only be adequately and appropriately applied by well-trained ecologists and scientists.

6 Data Collection, Recording, and Calculation of Functional Capacity

Cover Types

The following tabulation lists cover types prevalent among the floodplain complexes of alluvial gravel-bed rivers of the northern Rocky Mountains.

Cover Type 1	Mature conifer dominating the canopy with interspersed mature cottonwood. Soils generally developing an A-Horizon.
Cover Type 2	Mature cottonwood dominated (>6-m height and >10-cm dbh). May have early stages of conifers that have not reached the forest canopy or may be entirely devoid of conifers.
Cover Type 3	Immature pole cottonwood 2-6 m in height and <10-cm dbh. May also have interspersion of willow. Soils are generally cobble dominated with fine sediments accumulating over the surface.
Cover Type 4	Cottonwood or willow seedlings and early seral stages up to 2 m in height. Substrate often with exposed cobble, but may also include deposited fines from flooding. Generally soils are unstained by organics, indicating very early soil development.
Cover Type 5	Filled or partially filled abandoned channel dominated by mix of willows, alder, shrubs, and interspersed herbaceous cover. Also, often the dominant cover type along edge of backwaters. Soils are generally composed of deeper fines (>10 cm) with a developing A-Horizon
Cover Type 6	Herbaceous vegetation dominated, but may have interspersion of an occasional shrub (<10% of cover). This cover type is often associated with a filled side channel or abandoned back channel, but may be on any surface type.
Cover Type 7	Exposed cobble riverbed during base flow and inundated during most annual high flows. May have very sparse herbaceous vegetation or an occasional cottonwood or willow seedling composing <10% of cover.
Cover Type 8	Main-channel surface during base flow; may be in a single tread channel or may be braided w/ islands.
Cover Type 9	Off main channel water at the surface during base flow; includes springbrooks, oxbows, scour depressions and ponds, non-flow-through downstream connected side channels, and disconnected side channels.
Cover Type 10	Agricultural field, may be a meadow or plowed, often planted and hayed; may have origin as a forested surface, but now logged, or may have been a natural meadow.
Cover Type 11	Domestic or commercially developed land including homes, buildings, gravel pits, transportation corridors, etc.

Field Data Sheets

Field Data Sheets are presented in the following pages.

Photo Interpretation - Landscape Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Polygon #1 Cover Type _______ Area ___________

Polygon #2 Cover Type _______ Area ___________

Polygon #3 Cover Type _______ Area ___________

Polygon #4 Cover Type _______ Area ___________

Polygon #5 Cover Type _______ Area ___________

Polygon #6 Cover Type _______ Area ___________

Polygon #7 Cover Type _______ Area ___________

Polygon #8 Cover Type _______ Area ___________

Polygon #9 Cover Type _______ Area ___________

Polygon #10 Cover Type _______ Area ___________

Polygon #11 Cover Type _______ Area ___________

Polygon #12 Cover Type _______ Area ___________

Polygon #13 Cover Type _______ Area ___________

Polygon #14 Cover Type _______ Area ___________

Polygon #15 Cover Type _______ Area ___________

Polygon #16 Cover Type _______ Area ___________

Polygon #17 Cover Type _______ Area ___________

Polygon #18 Cover Type _______ Area ___________

Polygon #19 Cover Type _______ Area ___________

Polygon #20 Cover Type _______ Area ___________

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Landscape Assessment Area

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder ____

Proportionality of Landscape Features .... $V_{COMPLEX}$ **Subindex Score**

Floodplain Habitat Connectivity .... V_{HABCON} **Subindex Score**

Geomorphic Modification .... V_{GEOMOD} **Subindex Score**

Macrotopographic Complexity .... V_{MACRO} **Subindex Score**

Frequency of Surface Flooding .... $V_{SURFREQ}$ **Subindex Score**

Frequency of Subsurface Flooding .... $V_{SUBFREQ}$ **Subindex Score**

Landuse in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Proportional Landuse .... $V_{LANDUSE}$ Subindex Score

LU is the Variable Subindex Score for $V_{LANDUSE}$ by Polygon

Polygon #1	LU______	Area _____
Polygon #2	LU______	Area _____
Polygon #3	LU______	Area _____
Polygon #4	LU______	Area _____
Polygon #5	LU______	Area _____
Polygon #6	LU______	Area _____
Polygon #7	LU______	Area _____
Polygon #8	LU______	Area _____
Polygon #9	LU______	Area _____
Polygon #10	LU______	Area _____
Polygon #11	LU______	Area _____
Polygon #12	LU______	Area _____
Polygon #13	LU______	Area _____
Polygon #14	LU______	Area _____
Polygon #15	LU______	Area _____
Polygon #16	LU______	Area _____
Polygon #17	LU______	Area _____
Polygon #18	LU______	Area _____
Polygon #19	LU______	Area _____
Polygon #20	LU______	Area _____
		Total _____

$$V_{LANDUSE} = \sum \frac{LU \times PC}{TC}$$

where

LU = Land Use Score for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for $V_{LANDUSE}$

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

OM Decomposition in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Decomposition of Organic Matter .... $V_{ORGDECOMP}$ Subindex Score

OM is the Variable Subindex Score for $V_{ORGDECOMP}$ by Polygon

Polygon #1	OM score______	Area ______
Polygon #2	OM score______	Area ______
Polygon #3	OM score______	Area ______
Polygon #4	OM score______	Area ______
Polygon #5	OM score______	Area ______
Polygon #6	OM score______	Area ______
Polygon #7	OM score______	Area ______
Polygon #8	OM score______	Area ______
Polygon #9	OM score______	Area ______
Polygon #10	OM score______	Area ______
Polygon #11	OM score______	Area ______
Polygon #12	OM score______	Area ______
Polygon #13	OM score______	Area ______
Polygon #14	OM score______	Area ______
Polygon #15	OM score______	Area ______
Polygon #16	OM score______	Area ______
Polygon #17	OM score______	Area ______
Polygon #18	OM score______	Area ______
Polygon #19	OM score______	Area ______
Polygon #20	OM score______	Area ______
		Total ______

$$V_{ORGDECOMP} = \sum \frac{OM \times PC}{TC}$$

where:

OM = Variable Subindex Score of the OMDF for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for $V_{ORGDECOMP}$

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Tree Density in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Tree Density .... **V_{DTREE} Subindex Score**

DT is the Variable Subindex Score for V_{DTREE} by Polygon

Polygon #1	DT score______	Area ______
Polygon #2	DT score______	Area ______
Polygon #3	DT score______	Area ______
Polygon #4	DT score______	Area ______
Polygon #5	DT score______	Area ______
Polygon #6	DT score______	Area ______
Polygon #7	DT score______	Area ______
Polygon #8	DT score______	Area ______
Polygon #9	DT score______	Area ______
Polygon #10	DT score______	Area ______
Polygon #11	DT score______	Area ______
Polygon #12	DT score______	Area ______
Polygon #13	DT score______	Area ______
Polygon #14	DT score______	Area ______
Polygon #15	DT score______	Area ______
Polygon #16	DT score______	Area ______
Polygon #17	DT score______	Area ______
Polygon #18	DT score______	Area ______
Polygon #19	DT score______	Area ______
Polygon #20	DT score______	Area ______
		Total ______

$$V_{DTREE} = \sum \frac{DT \times PC}{TC}$$

where:

DT = Variable Subindex Score of the mean tree density for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for **V_{DTREE}**

Shrub Coverage in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Pole Cottonwood, Willow, Shrub, and
Sapling Coverage..**V_{SHRUB} Subindex Score**

SB is the Variable Subindex Score for V_{SHRUB} by Polygon

Polygon #1	SB score_______	Area ______
Polygon #2	SB score_______	Area ______
Polygon #3	SB score_______	Area ______
Polygon #4	SB score_______	Area ______
Polygon #5	SB score_______	Area ______
Polygon #6	SB score_______	Area ______
Polygon #7	SB score_______	Area ______
Polygon #8	SB score_______	Area ______
Polygon #9	SB score_______	Area ______
Polygon #10	SB score_______	Area ______
Polygon #11	SB score_______	Area ______
Polygon #12	SB score_______	Area ______
Polygon #13	SB score_______	Area ______
Polygon #14	SB score_______	Area ______
Polygon #15	SB score_______	Area ______
Polygon #16	SB score_______	Area ______
Polygon #17	SB score_______	Area ______
Polygon #18	SB score_______	Area ______
Polygon #19	SB score_______	Area ______
Polygon #20	SB score_______	Area ______
		Total ______

$$V_{SHRUB} = \sum \frac{SB \times PC}{TC}$$

where:

SB = Variable Subindex Score of the mean % coverage of pole cottonwood, willow, or shrub for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for V_{SHRUB}

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Herbaceous Coverage in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Herbaceous Plant Coverage.. V_{HERB} Subindex Score

HB is the Variable Subindex Score for V_{HERB} by Polygon

Polygon #1	HB score______	Area ______
Polygon #2	HB score______	Area ______
Polygon #3	HB score______	Area ______
Polygon #4	HB score______	Area ______
Polygon #5	HB score______	Area ______
Polygon #6	HB score______	Area ______
Polygon #7	HB score______	Area ______
Polygon #8	HB score______	Area ______
Polygon #9	HB score______	Area ______
Polygon #10	HB score______	Area ______
Polygon #11	HB score______	Area ______
Polygon #12	HB score______	Area ______
Polygon #13	HB score______	Area ______
Polygon #14	HB score______	Area ______
Polygon #15	HB score______	Area ______
Polygon #16	HB score______	Area ______
Polygon #17	HB score______	Area ______
Polygon #18	HB score______	Area ______
Polygon #19	HB score______	Area ______
Polygon #20	HB score______	Area ______
		Total ______

$$V_{HERB} = \sum \frac{HB \times PC}{TC}$$

where:

HB = Variable Subindex Score of the mean % herbaceous coverage for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for V_{HERB}

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Large Wood Debris in Floodplain Assessment Area

Site Information Site/Project Name _____________________ Date __/__/__

Team/Recorder ____

Large Wood Debris .... V_{LWD} Subindex Score

LWD is the Variable Subindex Score for V_{LWD} by Polygon

Polygon #1	LWD score_______	Area ______
Polygon #2	LWD score_______	Area ______
Polygon #3	LWD score_______	Area ______
Polygon #4	LWD score_______	Area ______
Polygon #5	LWD score_______	Area ______
Polygon #6	LWD score_______	Area ______
Polygon #7	LWD score_______	Area ______
Polygon #8	LWD score_______	Area ______
Polygon #9	LWD score_______	Area ______
Polygon #10	LWD score_______	Area ______
Polygon #11	LWD score_______	Area ______
Polygon #12	LWD score_______	Area ______
Polygon #13	LWD score_______	Area ______
Polygon #14	LWD score_______	Area ______
Polygon #15	LWD score_______	Area ______
Polygon #16	LWD score_______	Area ______
Polygon #17	LWD score_______	Area ______
Polygon #18	LWD score_______	Area ______
Polygon #19	LWD score_______	Area ______
Polygon #20	LWD score_______	Area ______
		Total ______

$$V_{LWD} = \sum \frac{LWD \times PC}{TC}$$

where:

LWD = Variable Subindex Score of the mean LWD density for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for V_{LWD}

Native Plant Coverage in Floodplain Assessment Area

Site Information Site/Project Name ____________________ Date __/__/__

Team/Recorder ____

Percent Coverage by Native Plants..............................V_{NPCOV} Subindex Score

NPC is the Variable Subindex Score for V_{NPCOV} by Polygon

Polygon #1	NPC score______	Area ______
Polygon #2	NPC score______	Area ______
Polygon #3	NPC score______	Area ______
Polygon #4	NPC score______	Area ______
Polygon #5	NPC score______	Area ______
Polygon #6	NPC score______	Area ______
Polygon #7	NPC score______	Area ______
Polygon #8	NPC score______	Area ______
Polygon #9	NPC score______	Area ______
Polygon #10	NPC score______	Area ______
Polygon #11	NPC score______	Area ______
Polygon #12	NPC score______	Area ______
Polygon #13	NPC score______	Area ______
Polygon #14	NPC score______	Area ______
Polygon #15	NPC score______	Area ______
Polygon #16	NPC score______	Area ______
Polygon #17	NPC score______	Area ______
Polygon #18	NPC score______	Area ______
Polygon #19	NPC score______	Area ______
Polygon #20	NPC score______	Area ______
		Total ______

$$V_{NPCOV} = \sum \frac{NPC \times PC}{TC}$$

where:

NPC = Variable Subindex Score of the mean % native plant coverage for Polygon
PC = Area of Polygon
TC = Total Area of Polygons in WAA determined for V_{NPCOV}

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Soils Field Data Sheet

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder ____

Cover Types 1-6 Only

	Thickness of O-Horizon (cm)	Thickness of SMS-Horizon (cm)	Color Value of SMS-Horizon
Polygon #1			
Polygon #2			
Polygon #3			
Polygon #4			
Polygon #5			
Polygon #6			
Polygon #7			
Polygon #8			
Polygon #9			
Polygon #10			
Polygon #11			
Polygon #12			
Polygon #13			
Polygon #14			
Polygon #15			
Polygon #16			
Polygon #17			
Polygon #18			
Polygon #19			
Polygon #20			

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Vegetation and Large Wood Debris Field Data Sheet

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder ___________________________

Vegetation Summary of Data	**Plot #1**	**Plot #2**	**Plot #3**	**Average**
Tree	________	________	________	________
Shrub	________	________	________	________
Herbs	________	________	________	________
Native Tree	________	________	________	________
Native Shrub	________	________	________	________
Native Herbs	________	________	________	________

Large Wood Debris Summary of Data	**Transect #1**	**Transect #2**	**Transect #3**	**Average**
Density (number/transect; 10 by 50 m)	________	________	________	________

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Functional Capacity Indices 1-4

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder ____

Function 1: Surface-Groundwater Storage and Flow **F_1 FCI**

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{SUBFREQ} + V_{MACRO}}{3}\right) \times V_{GEOMOD}\right]^{1/2}$$

Function 2: Nutrient Cycling **F_2 FCI**

$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE}}{3}\right) \times V_{COMPLEX} \times V_{ORGDECOMP}\right]^{1/3}$$

Function 3: Retention of Organic and Inorganic Particles **F_3 FCI**

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{MACRO} + V_{COMPLEX} + V_{LWD}}{4}\right) \times V_{GEOMOD}\right]^{1/2}$$

Function 4: Generation and Export of Organic Carbon **F_4 FCI**

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{MACRO}}{2}\right) \times \left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE}}{3}\right)\right]^{1/2}$$

Functional Capacity Indices 5-8

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder ____

Function 5: Characteristic Plant Community **F_5 FCI**

$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE} + V_{COMPLEX}}{4}\right) \times V_{NPCOV}\right]^{1/2}$$

Function 6: Characteristic Aquatic Invertebrate Food Webs **F_6 FCI**

$$FCI = \left[\left(\frac{V_{SURFREQ} + V_{SUBFREQ} + V_{MACRO} + V_{COMPLEX}}{4}\right)\right]$$

Function 7: Characteristic Vertebrate Habitats **F_7 FCI**

$$FCI = \left[\left(\frac{V_{HERB} + V_{SHRUB} + V_{DTREE} + V_{NPCOV}}{4}\right) \times \left(\frac{V_{SURFREQ} + V_{MACRO} + V_{COMPLEX} + V_{HABCON}}{4}\right)\right]^{1/2}$$

Function 8: Floodplain Interspersion and Connectivity **F_8 FCI**

$$FCI = \left[\left(\frac{V_{LANDUSE} + V_{HABCON} + V_{COMPLEX}}{3}\right) \times \left(\frac{V_{MACRO} + V_{SURFREQ} + V_{SUBFREQ}}{3}\right) \times V_{GEOMOD}\right]^{1/3}$$

HGM Functional Assessment of River Floodplains:
Rocky Mountain Gravel-Bed Rivers

Vegetation Plots and Field Data

Site Information Site/Project Name ______________________ Date __/__/__

Team/Recorder___________________________

Polygon # _____ Area_____ Cover Type _______________

Species Composition by Plot:		**Plot #1 Density or % Cover**	**Plot #2 Density or % Cover**	**Plot #3 Density or % Cover**	**Average Density or % Cover**
Species Name	**Native/Exotic**				

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Appendix A
Glossary

A-Horizon: A mineral soil horizon at the soil surface or below an O-Horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

Assessment Model: A simple model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

Assessment Objective: The reason that an assessment of wetland functions is being conducted. Assessment objectives normally fall into one of three categories. These include: documenting existing conditions, comparing different wetlands at the same point in time (e.g., alternatives analysis), and comparing the same wetland at different points in time (e.g., impact analysis or mitigation success).

Assessment Team (A-Team): An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

Avulsion: When a main channel moves dramatically from one location to another on the floodplain. Avulsion is an integral part of cut-and-fill alluviation. Avulsion processes generally recapture old channels making them now the new channel.

Channel: A natural stream or river or an artificial feature such as a ditch or canal that exhibits features of bed and bank and conveys water primarily unidirectionally downgradient.

Contemporary Floodplain: During the late Pleistocene period many rivers of the Reference Domain carried vast glacial meltwaters. There are consequently broad floodplains with distinct fluvially formed wetlands that have not been inundated by the river in thousands of years. These floodplain features currently rest on high floodplain terraces. The contemporary floodplain is restricted to that portion of the river valley that has been formed by contemporary flows and fluvial processes.

Direct Impacts: Project impacts that result from direct physical alteration of a wetland such as the placement of dredge or fill.

Direct Measure: A quantitative measure of an assessment model variable.

Functional Assessment: The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using an assessment model to determine a functional capacity index.

Functional Capacity: The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape and interaction between the two.

Functional Capacity Index (FCI): An index of the capacity of a wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates the wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes.

Highest Sustainable Functional Capacity: The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding landscape are undisturbed.

Hydrogeomorphic Unit: Hydrogeomorphic units are areas within a wetland assessment area that are relatively homogenous with respect to ecosystem scale characteristics such as microtopography, soil type, vegetative communities, or other factors that influence function. Hydrogeomorphic units may be the result of natural or anthropogenic processes. See **Partial Wetland Assessment Area.**

Hydrogeomorphic Wetland Class: The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes, including depression, fringe, slope, riverine, and flat.

Hyporheic Zone: Refers to that portion of a stream or river that is under or adjacent to the channel and is composed primarily of water whose origin is from the river. Gravel-bed rivers, as described in this Guidebook, often have an extensive hyporheic zone, extending several meters in depth and possibly extending for hundreds of meters away from the main channel.

In-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetland of the same regional wetland subclass.

Indicator: Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

Indirect Impacts: Impacts resulting from a project that occur concurrently or at some time in the future away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

Indirect Measure: A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

Interflow: The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake. See **Thoroughflow** for comparison.

Jurisdictional Wetland: Area that meets the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987) or its successor.

Mitigation: Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Mitigation Plan: A plan for replacing lost functional capacity resulting from project impacts.

Mitigation Ratio: The ratio of the Functional Capacity Units (FCUs) lost in a Wetland Assessment Area (WAA) to the FCUs gained in a mitigation wetland.

Mitigation Wetland: A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

Model Variable: A characteristic of the wetland ecosystem or surrounding landscape that influences its capacity to perform a function.

O-Horizon: A layer with more than 12 to 18 percent by weight (50 percent by volume) organic C. Form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc., partially decomposed plant debris (Oe), or totally decomposed organic material (Oa) such as muck.

Offsite Mitigation: Mitigation that is done at a location physically separated from the site at which the original impacts occurred, possibly in another watershed.

Out-of-kind Mitigation: Mitigation in which lost function capacity is replaced in a wetland of a different regional wetland subclass.

Paleochannel: Refers specifically to any old channel on the floodplain surface. A paleochannel may currently contain a floodplain springbrook, a fluvial-depressional wetland, or a flood channel. Paleochannels may be at the surface or may be subsurface, forming zones of preferential flow through the floodplain. Paleochannels are very important to maintaining high-flow pathways and connectivity of the hyporheic zone with the main channel.

Partial Wetland Assessment Area (PWAA): A portion of a WAA that is identified *a priori,* or while applying the assessment procedure, because it is relatively homogeneous and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally or as a result of anthropogenic disturbance. See **Hydrogeomorphic Unit**.

Project Alternatives: Different ways in which a given project can be assessed. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, and other ways.

Project Area: The area that encompasses all activities related to an ongoing or proposed project.

Project Target: The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

Red Flag Features: Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, state, regional, or local level and may be official or unofficial.

Reference Domain: The geographic area from which reference wetlands are selected. A Reference Domain may or may not include the entire geographic area in which a regional wetland subclass occurs.

Reference Standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest sustainable level of functioning) across the suite of functions performed by the regional wetland subclass. The highest level of Functional Capacity is assigned an index value of 1.0 by definition.

Reference Wetlands: Wetland sites that encompass the variability of a regional wetland subclass in a Reference Domain. Reference Wetlands are used to establish the range of conditions for construction and calibration of functional indices and establish Reference Standards.

Region: A geographic area that is relatively homogenous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional Wetland Subclass: Wetlands within a region that are similar based on hydrogeomorphic classification factors. There may be more than one Regional Wetland Subclass identified within each Hydrogeomorphic Wetland Class, depending on the diversity of wetlands in a region and the assessment objectives.

Seston: Small organic particles carried in the water column and transported downstream.

Site Potential: The highest level of functioning possible given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by Reference Standards for the Reference Domain, and it may be equal to or less than the Functional Capacity of a Wetland Ecosystem.

Throughflow: The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake. See **Interflow** for comparison.

Variable: An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of the wetland to perform a function.

Variable Condition: The condition of a variable as determined through quantitative or qualitative measure.

Variable Index: A measure of how an Assessment Model variable in a wetland compares to the Reference Standards of a Regional Wetland Subclass in a Reference Domain.

Wetland Ecosystem: In 404: ".......areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Corps Regulation 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, Wetland Ecosystems are three-dimensional segments of the natural world where the presence of water, at or near the surface, creates conditions leading to the development of redoxomorphic soil conditions and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Wetland Assessment Area (WAA): The wetland area to which results of an assessment are applied.

Wetland Banking: The process of creating a "bank" of created, enhanced, or restored wetlands to serve at a future date as mitigation for project impacts.

Wetland Functions: The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape and their interaction.

Wetland Creation: The process of creating a wetland in a location where a wetland did not previously exist. Wetland creation is typically done for mitigation.

Wetland Enhancement: The process of increasing the capacity of a wetland to perform one or more functions. Wetland enhancement can increase functional capacity to levels greater than the highest sustainable Functional Capacity achieved under Reference Standard conditions, but usually at the expense of sustainability or at a reduction of Functional Capacity of other functions. Wetland Enhancement is typically done for mitigation.

Wetland Restoration: The process of restoring wetland function in a degraded wetland. Restoration is typically done as mitigation.

Wetland Values: A confusing term that mixes wetland ecological functions with personal or societal preferences. Has also been used in various economic contexts. This term should be avoided if for no other reason than lack of clarity.

Value of Wetland Function: The relative importance of a wetland function to an individual or group.

Appendix B
Documenting Data

SUBINDEX SCORES													
River Site	Complex	Geomod	Habcon	Landuse	Macro	Subfreq	Surfreq	Orgdecomp	Dtree	Shrub	Herb	Npcov	Lwd
Schaffer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nyack	0.95	0.95	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	1.00
Lamar	0.50	1.00	0.80	0.30	1.00	1.00	1.00	1.00	0.10	0.00	1.00	1.00	0.20
Usnake	0.70	0.60	0.80	0.60	1.00	1.00	0.80	1.00	1.00	0.80	1.00	0.40	0.75
Lsnake	0.70	0.90	0.95	0.80	1.00	1.00	0.40	1.00	0.70	0.50	1.00	0.60	0.20
Gkohrs	0.50	0.75	0.80	0.60	1.00	1.00	0.75	1.00	0.60	0.80	1.00	0.40	0.40
Mso	0.10	0.20	0.10	0.15	0.40	0.50	0.35	0.40	0.50	.060	0.80	0.20	0.10
Btrrot	0.85	0.70	1.00	0.80	1.00	0.90	0.90	1.00	0.90	0.80	0.90	0.70	0.80

FUNCTION SCORES								
River Site	F1	F2	F3	F4	F5	F6	F7	F8
Schaffer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nyack	0.97	0.98	0.97	1.00	0.89	0.99	0.97	0.95
Lamar	1.00	0.57	0.82	0.61	0.63	0.88	0.66	0.81
Usnake	0.75	0.87	0.70	0.92	0.59	0.88	0.81	0.73
Lsnake	0.85	0.80	0.72	0.72	0.66	0.78	0.73	0.84
Gkohrs	0.83	0.74	0.70	0.84	0.54	0.81	0.73	0.76
Mso	0.29	0.29	0.22	0.49	0.32	0.34	0.35	0.21
Btrrot	0.81	0.90	0.79	0.91	0.78	0.91	0.88	0.83

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14. ABSTRACT

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified including: determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

This report uses the HGM Approach to develop a Regional Guidebook for assessing the functions of riverine floodplains in the northern Rocky Mountains. The report: (a) introduces the HGM developmental history, (b) provides a brief overview of the major components of the HGM Approach and discusses the development and application phases, (c) characterizes factors that influence wetland functions on riverine floodplains in the northern Rocky Mountains, (d) discusses the wetland functions, model variables, and functional indices, and (e) provides the necessary assessment protocols, field methods, and computing procedures.

15. SUBJECT TERMS

404 Regulatory Program	Evaluation	Hydrogeomorphic (HGM) Approach	Landscape	Reference Wetlands
Assessment	Function	Hydrology	Method	Restoration
Clarification	Functional Assessment	Impact Analysis	Model	Value
Clean Water Act	Functional Profile	Index	National Action Plan	Wetland
Ecosystem	Geomorphology	Indicators	Procedure	

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